# Design Requirements Manual

## Division of Technical Resources

*The formulae*

$$\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_i U_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0) \qquad \frac{\partial \rho U_i k}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\left(\mu+\frac{\mu_T}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right)+P+G-\rho\varepsilon$$

$$\frac{\partial \rho U_i \varepsilon}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\left(\mu+\frac{\mu_T}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_i}\right)+(C_1-C_{1RNG})\frac{\varepsilon}{k}(\mathbf{P}+C_3\mathbf{G})-C_2\rho\frac{\varepsilon^2}{k}$$

*for building*

$$\frac{\partial}{\partial x_i}(\rho\overline{U}_i\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{T}}{\partial x_i}-\rho\overline{u_i'h'}\right)$$

$$-\rho\overline{u_i'u_j'}=\mu_T\left(\frac{\partial \overline{U}_i}{\partial x_j}+\frac{\partial \overline{U}_j}{\partial x_i}\right)-\tfrac{2}{3}\rho k\partial$$

*state of the art*

$$\frac{\partial}{\partial x_j}(\rho\overline{U}_i\overline{U}_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U}_i}{\partial x_j}-\rho\overline{u_i'u_j'}\right)+g_i(\rho-\rho_0)$$


$$\frac{\partial \rho U_i \varepsilon}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\left(\mu+\frac{\mu_T}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_i}\right)+C_1\frac{\varepsilon}{k}(P+C_3G)-C_2\rho\frac{\varepsilon^2}{k}$$

*biomedical research facilities.*

The National Institutes of Health

# Revisions

# Design Requirements Manual Last Update on 8/02/2010

| Location | Date Changed | Revisions |
|---|---|---|
| Section 8-2<br>8-2-10 A.<br>Page 8-16 | 8/2/10 | A. Water Closets:<br>Water closets shall be wall mounted, ~~6~~ 4.0 to 5.0 liter per flush (LPF) (~~1.6~~ 1.0 to 1.28 gallon per flush (GPF)), siphon jet type; with electronic hands-free flushometer that is hard wired on stand-by power. |
| Section 8-2<br>8-2-10 B.<br>Page 8-17 | 8/2/10 | B. Urinals:<br>All urinals shall be wall mounted, ~~4~~ 2.0 to 3.0 LPF (~~1.0~~ 0.5 to 0.8 GPF), and of the siphon jet or blowout action type, with electronic hands free flush, hardwired on stand-by power. |
| Section 8-2<br>8-2-10 C.<br>Page 8-17 | 8/2/10 | • Electronic hands-free faucets with arc or gooseneck spouts, hard wired and on stand-by power shall be provided for lavatories in ~~public~~ restrooms. Battery-powered operation is not acceptable. Laboratory sinks shall be rated for a water flow of 8 L/min (2 GPM). Restroom's lavatories with other than metering faucets shall be rated for a water flow of 1.5 to 1.9 L/min (0.4 to 0.5 GPM). Restroom's lavatories with metering faucets shall be rated for a water flow of 0.8 to 1 L/min (0.2 to 0.25 GPM). ~~and food service areas, with flow rate between 4 l/min and 10 l/min (1.0 and 2.5 GPM).~~ The cycle time (metering faucet) for ~~public~~ restroom's lavatory faucets shall be adjusted to maintain water conservation at not more than 1 liter per cycle (0.25 gallons per cycle). |
| Section 8-2<br>8-2-10 D.<br>Page 8-18 | 8/2/10 | Showers shall be rated for a water flow of 8 L/min (2.0 GPM). |
| Section 6-3<br>6-3-00 A.1<br>Page 6-52 | 8/2/10 | A.1 Hydronic pipe sizing:<br>Closed loop hydronic piping shall be sized per the following criteria:<br>• Piping ~~50~~ 100 mm (~~2~~ 4 in.) and smaller shall be sized for a maximum velocity of ~~1.2~~ 1.83 m/s ~~(4 fps)~~ (6 fps) and a maximum pressure drop of 0.4 kPa/m (4 ft./100 ft.) of piping.<br>• Piping larger than ~~50~~ 100 mm (~~2~~ 4 in.) shall be sized for a maximum velocity of 3.0 m/s (10 fps) and a maximum pressure drop of 0.4 kPa/m (4 ft./100ft.) of piping. |
| Section 6-1<br>6-1-00 D.1<br>Page 6-3 | 5/12/10 | Winter 21 + 1 (70 + 2) ~~40 ± 10~~ 30 ± 5 |

| Location | Date Changed | Revisions |
|---|---|---|
| Section 6-1<br>6-1-00 D.9<br>Page 6-9 | 5/12/10 | These rooms shall be heated to maintain a space temperature of ~~20°C (68°C)~~ 18°C (65°C). |
| Section 6-1<br>6-1-00 F.1<br>Page 6-14 | 5/12/10 | Winter 21 + 1 (70 + 2) ~~40 ± 10~~ 30 ± 5 |
| Section 6-1<br>6-1-00 F.2<br>Page 6-14 | 5/12/10 | The minimum outdoor air ventilation rate for laboratory space is 6 air-changes per hour, regardless of space cooling load. |
| Section 6-1<br>6-1-00 G.1<br>Page 6-17 | 5/12/10 | Winter 21 + 1 (70 + 2) ~~40 ± 10~~ 30 ± 5 |
| Section 6-1<br>6-1-00 G.1<br>Page 6-17,18 | 5/12/10 | Mouse 18 (65) – 26 (79) ~~40 – 70~~ 35 ± 5 (3,4)<br>Hamster 18 (65) – 26 (79) ~~40 – 70~~ 35 ± 5 (3,4)<br><br>(3) Refer To: "Ventilation Design Handbook on animal research facilities using static microisolators"; Volumes I and II, November 1998, Farhad Memarzadeh, PhD, P.E., NIH – Office of the Director, ORF Publication, Bethesda, MD<br><br>(4) Refer To ASHRAE 2005 Fundamentals Handbook, Chapter 10 "Environmental Control For Animals and Plants" |
| Section 6-2<br>6-2-00 A.1<br>Page 6-31 | 5/12/10 | Air-handling units (AHU) shall be designed to provide~~d~~ N+1 reliability and maintain 100% capacity in the event of a lead component failure. |
| Section 6-2<br>6-2-00 D.<br>Page 6-34,35, 36 | 5/12/10 | Casings……..<br>Exterior panel shall be ~~1.621 mm (16 gauge)~~ 1.316 mm (18 gauge) solid G90 galvanized steel. All interior panels shall be ~~1.316 mm (18 gauge)~~ 1.621 mm (16 gauge) solid G90 galvanized steel.<br><br>Coils……<br>The use of Turbulators is not acceptable.<br><br>Drain pans……<br>Drain pans shall extend a minimum of 12-in. downstream of the cooling coils. |

| Location | Date Changed | Revisions |
|---|---|---|
| Section 6-2<br>6-2-00 E.<br>Page 6-39,40 | 5/12/10 | Filter average efficiencies shall be MERV-8 (30%) and MERV-14 (95%) respectively, based on ASHRAE Standard ~~52.1~~ 52.2, ~~atmospheric dust-spot test efficiency~~ Minimum Efficiency Reporting Value (MERV).<br><br>Average efficiency of the final filters shall be MERV-14 (95%), based on ASHRAE Standard ~~52.1~~ 52.2, ~~atmospheric dust-spot test efficiency~~ Minimum Efficiency Reporting Value.<br><br>Humidifiers shall be steam ~~atomizing~~ separator type with jacketed steam injection, which do not require a drain from the steam manifold. They may be located within air-handling units or ~~mounted on~~ installed in the supply air ductwork. Duct mounted ~~humidifiers~~ steam distribution manifold shall be installed within a fully welded stainless steel ductwork section. The stainless steel section shall extend 0.6 m (2 ft.) upstream the ~~humidifier~~ manifold and at least 2 m (6 ft.) downstream the ~~humidifier~~ manifold. |
| Section 6-2<br>6-2-00 H.2<br>Page 6-42 | 5/12/10 | VFDs shall have a manual bypass ~~completely~~ independent of the drive ~~cabinet~~. |
| Exhibit X6-3-B<br>Page 6-76 | 5/12/10 | DD Un-pigmented polypropylene pipe, ASTM D4101, ASTM D2837, SDR 11 or schedule 80 ~~ASTM D2447~~, individual cap, sealed bag or ends. |
| Exhibit X6-3-C<br>Page 6-79 | 5/12/10 | XXVI Natural polypropylene, un-pigmented ASTM D4101, ~~ASTM D2839,~~ furnished in sealed nitrogen-charged bag. Socket fusion style or IR butt fusion style without use of embedded coils. |
| Section 4-5<br>4-5-10 B.1<br>Page 4-45 | 5/12/10 | ~~B.1 Autoclaves:~~<br>~~For maximum flexibility, an autoclave shall be provided on each floor where microbiological research is performed. Sufficient space shall be provided in the autoclave room to ensure easy access to the serviceable areas of the autoclave. The A/E shall review the requirements of the building personnel when designing and specifying autoclave space. Autoclave space shall be finished with epoxy coatings and shall not have a suspended, acoustical ceiling. This area shall be thoroughly caulked and sealed to promote cleanliness and reduce pest harborage. The space shall have adequate exhaust capacity to remove heat, steam, and odors generated by the use of the autoclave(s). A canopy hood shall be provided over each door of the autoclave. The autoclave space shall operate at negative pressure to the surrounding areas~~ |

| Location | Date Changed | Revisions |
|---|---|---|
| Section 4-5<br>4-5-00 C.1<br>Page 4-41 | 5/12/10 | C.3 Autoclaves:<br>For maximum flexibility, an autoclave shall be provided on each floor where micro-biological research is performed. Sufficient space shall be provided in the autoclave room to ensure easy access to the serviceable areas of the autoclave. The A/E shall review the requirements of the building personnel when designing and specifying autoclave space. Autoclave space shall be finished with epoxy coatings and shall not have a suspended, acoustical ceiling. This area shall be thoroughly caulked and sealed to promote cleanliness and reduce pest harborage. The space shall have adequate exhaust capacity to remove heat, steam, and odors generated by the use of the autoclave(s). A canopy hood shall be provided over each door of the autoclave. The autoclave space shall operate at negative pressure to the surrounding areas |
| Section 4-5<br>4-5-00 C.2<br>Page 4-40 | 5/12/10 | C.2 ~~Placement of Biological Safety Cabinet (BSC) in Lab Module:~~<br><br>C.2 BSC Placement Requirements for All New Buildings and Renovations: (See Appendix I) |
| Appendix I<br>New Appendix | 5/12/10 | Biosafety Cabinet (BSC) Placement Requirements for new Buildings and Renovations |
| Section 9-1<br>9-1-30 C.<br>Page 9-4 | 5/12/10 | ~~C. Engineering Analysis:~~<br>~~All designs for new structures (including designs for new wing additions or other additions to existing structures that modify the height and area or change the use group), modifications, renovations, and alterations that include the addition or modification of fire protection systems or egress components shall have a "Fire Protection Engineering Analysis" performed by a registered fire protection engineer at the concept and final design phase. A registered fire protection engineer is defined as a professional engineer (PE) with expertise in the field of fire protection engineering as demonstrated by passing the National Council of Examiners for Engineers and Surveyors "Principals and Practice Examination" in the discipline of fire protection engineering. A "Fire Protection Engineering Analysis" shall contain the following key features:~~<br><br>~~• Overview of all active and passive fire protection for the proposed facility.~~<br>~~• List of all fire protection features required by the codes or standards referenced above. All fire protection and life safety features shall be suitably integrated.~~<br>~~• Type of construction.~~<br>~~• Classification of occupancy.~~<br>~~• Analysis of fire resistance ratings required by hazardous materials in excess of the exempt amounts identified in the IBC.~~<br>~~• Fire-resistance rating of all structural components (floors, columns, and bearing~~ |

| Location | Date Changed | Revisions |
|---|---|---|
| | | walls, exterior walls, and roof), clearly specifying the applicable industry design guide and/or UL designation for the protection scheme for each component.<br>• Location of all fire-rated assemblies used for the enclosure of all stairs, shafts, openings, and/or the separation of fire areas and the fire-rated components (doors, dampers) necessary to protect openings in these barriers; indicating the hourly rating of these barriers and the components protecting openings, clearly specifying the applicable industry design guide and/or UL designation for each barrier.<br>• Location of all smoke barriers and the smoke rated components (doors, dampers) necessary to protect openings in these barriers; clearly specifying the applicable industry design guide and/or UL designation for each smoke rated component.<br>• Building separation or exposure protection, including temporary construction separation protection required by NFPA 241 requirements.<br>• Fire protection criteria references.<br>• Occupant load and exit calculations based on NFPA 101 Life Safety Code (LSC) requirements, including analysis of existing exit requirements during construction.<br>• Automatic extinguishing systems, including the identification of sprinkler protected areas and areas protected by other automatic suppression means.<br>• Manual extinguishing equipment, including type and size of equipment, and areas of coverage. There is no longer a requirement to install manual extinguishing units in laboratories on the Bethesda and Poolesville campuses. Other areas of the country shall follow the local jurisdictional requirements.<br>• Fire standpipe system, including hose valve size and thread type, and areas of coverage.<br>• Water supply analysis determining system requirements and adequacy of the present water supply, and the need for a fire pump assembly. The water supply data shall be obtained by the A/E via fire hydrant flow tests. The water supply analysis shall include consideration of hydraulic gradient/supply pressure fluctuations, peak demand conditions, and known future expansion loads on the supply main to provide an accurate representation of available supply conditions. Flow test results and the associated analysis and calculations shall be transmitted to DFM for concurrence before use in the design process.<br>• Description of Fire Department (FD) access, including location of FD key box, roof access, distance of fire hydrants from the structure, distance of each side of the structure from the street, distance of fire standpipe and/or sprinkler connections from the road, and distance of fire standpipe and/or sprinkler connections from the closest fire hydrant.<br>• Automatic detection/fire alarm system, including identification of detection requirements, zoning arrangements, elevator control system interconnection, and evacuation alarm description. |

| Location | Date Changed | Revisions |
|---|---|---|
| Section 6-1<br>6-1-00 D.7.f<br>Page 6-8 | 8/27/09 | ~~Low flow and auxiliary air-type fume hoods shall NOT be used in any NIH facilities. In the event of a retrofit application, the A/E shall investigate the capacities of the existing system inclusive of the auxiliary air, and laboratory supply and exhaust system characteristics. Once it has been established that the system can support the addition or replacement of an existing low flow fume hood or auxiliary air fume hood, this information shall be forwarded to the project officer for approval before the design is allowed to proceed.~~<br><br>Low flow fume hoods may be used at NIH as long as they meet ALL the requirements as outlined in the NIH / ASHRAE 110 Modified Fume Hood Testing Protocol. In addition, fume hoods shall comply with the testing requirements of the listed NIH onsite testing specification sections 15991, 15992 and Appendix E. 3 "Fume Hood Testing and Alarm System." The face velocity of low flow hoods should *NEVER be below 0.41 m/s (80 fpm).*<br><br>Auxiliary air-type fume hoods shall NOT be used in any NIH facilities. In the event of a retrofit application, the A/E shall investigate the capacities of the existing system exclusive of the auxiliary air, and laboratory supply and exhaust system characteristics. Once it has been established that the system can support the addition or replacement of an existing fume hood, this information shall be forwarded to the project officer for approval before the design is allowed to proceed. |
| Section 7-3<br>7-3-00 E.1<br>Page 7-23 | 8/27/09 | There shall never be a condition in which the control system goes outside this range for more than two minutes ~~or goes positive for more than 30 seconds.~~ and directional airflow must be sustained by drawing air into the laboratory from "clean" areas toward 'potentially contaminated areas'. The laboratory shall be designed such that under failure conditions the airflow will not be reversed. |
| Section 7-3<br>7-3-00 F.2<br>Page 7-25 | 8/27/09 | ~~The maximum duration of a positive pressure in a BSL3 animal holding room shall be 30 seconds.~~<br><br>The ventilation system must provide sustained directional airflow by drawing air into the animal room from "clean" areas toward 'potentially contaminated areas'. The animal room shall be designed such that under failure conditions the airflow will not be reversed. |
| Section 7-1<br>7-1-10 B.1<br>Page 7-2 | 6/9/09 | ~~The DRM shall provide under separate cover an appendix containing Standards Control Diagrams and Sequence of Operation write-ups to support standardization.~~ |

| Location | Date Changed | Revisions |
|---|---|---|
| Exhibit X1-5-A<br>Page 1-31 | 6/3/09 | Request For Variance form updated. |
| Section 6-1<br>6-1-00 E.5<br>Page 6-13 | 6/3/09 | Wet exhaust air from areas such as sterilizers, autoclaves, ~~glass/dishwashers,~~ glass washers, cage washers, and pot-washing equipment, etc shall be captured by using canopy-type stainless steel hoods at each equipment entrance and exit. |
| Exhibit X6-2-B<br>Page 6-50 | 6/3/09 | Low-pressure wet ~~process~~ exhaust air ductwork 500 ~~(2)~~ (11) Alum or ss<br><br>(11) Wet exhaust air ductwork serving sterilizers, autoclaves, and cage washers shall be stainless steel. |
| Section 6-2<br>6-2-00 A.<br>Page 6-30 | 4/23/09 | ~~Induction type terminal units shall not be utilized.~~<br><br>Laboratories that are provided with minimum required outdoor air ventilation and filtration from a central supply air system, supplemental terminal conditioning units shall be permitted to efficiently offset high cooling and heating loads without the use of single pass air from the central system using the guidance in the following references.<br><br>Reference;<br>1. Memarzadeh, "Energy Efficient Laboratory Design: A Novel Approach to Improve<br>Indoor Air Quality and Thermal Comfort"; American Biological Safety Association (ABSA) Journal, Vol. 12, No. 3, 2007<br>2. Memarzadeh, "Controlling Laboratory IAQ and Energy Costs"; Heating, Piping, and Air-Conditioning Engineering (HPAC), October, 2007 |
| Section 1-6<br>1-1-20 C.<br>Page 1-6 | 3/18/09 | Placing Fume Hoods and Biological Safety Cabinets in laboratories shall comply with the findings of the "Methodology for Optimization of Laboratory Hood Containment - Volumes I and II, November 1996, Farhad Memarzadeh, PhD, P.E., NIH – Office of the Director, ORF Publication, Bethesda, MD" |
| Section 2-3<br>2-3-00<br>Page 2-9 | 3/18/09 | Placing Fume Hoods and Biological Safety Cabinets in laboratories shall comply with the findings of the "Methodology for Optimization of Laboratory Hood Containment - Volumes I and II, November 1996, Farhad Memarzadeh, PhD, P.E., NIH – Office of the Director, ORF Publication, Bethesda, MD" |

| Location | Date Changed | Revisions |
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| Section 2-5<br>2-5-10 B.<br>Page 2-102 | 2/5/09 | ~~BSL3 cabinet laboratories shall use a Class III BSC as the primary containment barrier.~~<br><br>In BSL3 laboratories all procedures involving the manipulation of infectious materials must be conducted within a BSC (preferably Class II or Class III), or other physical containment devices. |
| Section 2-5<br>2-5-10 C.<br>Page 2-102 | 2/5/09 | ~~BSL3 Cabinet Laboratory:~~ The BSL3 laboratory shall be designed to provide maximum containment of aerosolized infectious agents used in scientific research programs. Due to the dangerous nature of such studies, aerosolization ~~occurs~~ shall occur inside ~~a Class III cabinet~~ of the BSC, to ensure maximum protection of personnel and the surrounding environment |
| Section 2-5<br>2-5-30 F.3.<br>Page 2-106 | 2/5/09 | ~~HEPA filter testing requirements (IEST RP-CC034.1 {Sec.45} HEPA and ULPA Filter Leak Test (1999 or equivalent)~~<br><br>All HEPA filters shall be tested using IEST-RP-CC001.3 or an APPROVED equivalent test procedure. Poly-Alpha Olefin (PAO) shall be used in lieu of Di-Octyl Phthalate (DOP) as a traces gas. |
| Section 2-6<br>2-6-10 B.<br>Page 2-112 | 2/5/09 | ~~Safety equipment used in ABSL3 areas is primarily the biological safety cabinet (BSC). The BSC is the primary barrier of an ABSL3 environment for the use and manipulation of agents and the handling of infectious animals. If aerosolization studies are to be preformed, they are conducted in a Class III BSC. These BSCs are exhausted through double HEPA filters in series by separate and independent exhaust system. PPE, protective lab clothing, gloves and respiratory protection as required by BMBL and DOHS is worn.~~<br><br>In ABSL3 areas all procedures involving the manipulation of infectious materials, agents, and animals must be conducted within a BSC (preferably Class II or Class III), or other physical containment devices. These BSC s are exhausted through HEPA filters in series by separate and independent exhaust systems. PPE, protective lab clothing, gloves and respiratory protection as required by the BMBL and the DOHS shall be worn. |
| Section 2-6<br>2-6-30 F.3.<br>Page 2-119 | 2/5/09 | ~~HEPA filter testing requirements (IEST RP-CC034.1 {Sec.45} HEPA and ULPA Filter Leak Test (1999 or equivalent)~~<br><br>All HEPA filters shall be tested using IEST-RP-CC001.3 or an APPROVED equivalent test procedure. Poly-Alpha Olefin (PAO) shall be used in lieu of Di-Octyl Phthalate (DOP) as a traces gas. |

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|---|---|---|
| Appendix B | 1/6/09 | See Appendix A in the Facilities Development Manual. |
| Appendix E<br>E.1<br>Page E-1 | 1/6/09 | $-\frac{n V_{room}}{V_{room}}$ Clearly, the AV $_{room}\cong$ terms will cancel out, and we are left with the simple exponent value of ~~⊟~~n~~⊟~~; and we can, therefore, see that formula evolves to the following:<br>$C = C_0 e^{-n \frac{V_{room}}{V_{room}}} = C_0 e^{-n}$ The task for the consultant is simply to determine the value of ~~⊟~~n~~⊟~~, as a number of Room Volumes, that corresponds to: (1) a decrease in the ambient concentration to a level that is only 10% of the starting value (i.e. the ending concentration, ~~⊟~~$C_{90\%}$~~⊟~~, has the value $0.1C_o$]; and (2) a decrease in the ambient concentration to a level that is only 1% of the starting value [i.e. the ending concentration, $C_{99\%}$~~⊟~~, has a value, $0.01C_o$]. |
| Section 6-1<br>6-1-00 G.5<br>Page 6-22 | 12/1/08 | [For detailed calculations on downdraft table particle capture efficiency – See Appendix H] |
| Section 7-1<br>7-1-10 B.1<br>Page 7-2 | 11/19/08 | ~~The DRM shall provide under separate cover an appendix containing Standard Control Diagrams and Sequence of Operation write-ups to support standardization.~~ |
| Section 1-10<br>1-10-20<br>Page 1-72 | 11/18/08 | The NIH Division of Environmental Protection will ~~be providing~~ provide additional guidance ~~on a NIH Sustainable Design Manual to be completed in 2008~~. |
| Section 2-3<br>2-3-10 G.2<br>Page 2-27 | 11/18/08 | Recommended Laboratory ~~Shred~~ Shared Support Requirements: 4$^{O}$ c cold room, free standing equipment room and ice support room |

# Preface

# Preface

The 2008 National Institutes of Health (NIH) Design Requirements Manual for Biomedical Laboratories and Animal Research Facilities (DRM), formerly called the NIH Design Policy and Guidelines, is the only detailed design requirements and guidance manual for biomedical research laboratory and animal research facilities in the U.S. Compliance to the DRM, which promulgates minimum performance design standards for NIH owned and leased new buildings and renovated facilities, ensures that those facilities will be of the highest quality to support Biomedical research.

The Division of Technical Resources (DTR) in the NIH Office of Research Facilities (ORF) is responsible for developing and maintaining the DRM. It is also responsible for reviewing and approving its content and organization. DTR pursue, research and test state-of-the-art and innovative technology that may be applicable to biomedical research facilities, and incorporating research results and lessons-learned from the design and construction of NIH's unique biomedical research facilities into the DRM. The DRM is a dynamic document. Revisions are made as necessary. The Architect/Engineer (A/E) should refer to the revisions page before each use of the DRM to note any updates that have been made since the last use. The entire DRM will be revised on a three year cycle.

The DTR maintains state-of-the-art knowledge and develops new technologies to improve energy efficiency, maintenance and operations. ORF has conducted studies that are the basis for NIH's Bio-Environmental Engineering Research Program. These studies have set numerous National and International Standards for Better Indoor Air Quality and Greater Energy Conservation. The following standard setting organizations have adopted the NIH research findings: American National Standard Institutes (ANSI), American Society of Heating and Refrigeration, and Air Conditioning Engineers (ASHRAE), The American Institute of Architects (AIA) Academy of Architecture for Health, and the International Academy on Indoor Air Quality The results of these studies are incorporated in the 2008 DRM and new information will be added as it becomes available.

The 2008 edition constitutes a major restructuring and reorganization of the 2003 edition, with the addition of a vast amount of new and updated information for the A/E to use in the facility design process. The content additions and updates are based on lessons learned, original research and state-of-the-art technology and include:

a) NIH requirements for BSL/ABSL-3 & 4 (NEW)
b) Controls and Control Sequences (NEW)
c) NIH Commissioning Philosophy
d) NIH Decommissioning Philosophy
e) Enhanced vibration and noise criteria (NEW)
f) Strategy for an alternative means of performing pressure decay testing in a BSL-4 laboratory (NIH Equivalency Strategy) (NEW)
g) Caulking Checklist for Maximum Containment (NEW)
h) NIH Sustainability Philosophy and Requirements (NEW)

DTR established:

- 8 technical committees and an Executive Steering Committee to advise on DRM content.
- The committees included Mechanical, Plumbing, Controls, Special Topics, Electrical, Architectural, Animal Facilities, and Biocontainment.
- During 2005/2006 there were over 250 meeting hours
- More than 150 participants contributing their time.
- Technical expertise was provided by the Office of Research Services (ORS), Divisions of Radiation Safety (DRS), Occupational Health and Safety (DOHS), Fire Marshal (DFM), Police (DP), and Physical Security Management (DPSM), NIH Institutes and Centers (IC), other federal agencies including the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and representatives from the private sector.

The NIH Design Requirements Manual aligns the NIH facilities program with the ORF mission of: "Supporting NIH priorities by providing safe, secure, sound, healthy, and attractive facilities." This manual also aligns the ORF with a national imperative to be good stewards of America's real property assets. We extend our sincerest thanks to all of the people who helped to make the NIH Design Requirements Manual a reality.

/ S / August 27th 2008

Farhad Memarzadeh, Ph.D., P.E.
Director; Division of Technical Resources

/ S / August 27th 2008

Daniel G. Wheeland, P.E. Director; Office of Research Facilities Development and Operations

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# Acknowledgements & Table of Contents



# Acknowledgements

The effort to develop the NIH DRM could not have been accomplished without the dedication, contribution, and assistance of representatives from the NIH, other Federal Government agencies, and the private sector. Subcommittees were composed of architects, engineers, facility managers, operations and maintenance staff, scientists, and veterinarians to bring the broadest perspective to developing the DRM.

The NIH DRM Executive Steering Committee is a multi-discipline team comprising senior professionals from the Office of Research Facilities, the Office of Research Services, and the Office of the Director. The Executive Steering Committee is tasked with making final decisions regarding overall content, arbitrating difficult decisions, and approving the final document for publication.

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## Subcommittees:

Subcommittees for each discipline represented in the DRM met biweekly to revise the 2003 DRM. The ORF DPPA organized the subcommittees and led the revision effort. The NIH Project Team was comprised as follows:

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# Section 1-1: Plan of the Manual

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## 1-1-00 Policy

This section describes organization, maintenance, distribution and applicability of the NIH Design Requirements Manual (DRM). This Manual supersedes all of the NIH Design Policy and Guidelines. The NIH Design Requirements Manual is written in accordance with Section 3-4 "Design Guidelines" of Volume I of the HHS Facilities Program Manual.

### A. Manual Organization

1. The Design Requirements Manual consists of chapters, which represent major subject categories. The chapters are further broken down into sections, each of which shall set forth NIH design requirements and guidance with respect to NIH laboratory and vivarium design and rehabilitation. Exhibits/Appendices are included in the manual as necessary to disseminate examples, and additional detailed information.
2. The numbering system for manual chapters shall be as follows:

Example:
Chapter …….. 1
Section ……. 1-2
Sub-Section …… 1-2-10
Paragraph ……..…….. A
Subparagraph ……. A.1
Exhibit ……. X1-2-A
Exhibit ……. X1-2-B

The sections are generally organized in sub-sections as follows: Design Requirements, 1-1-00; Design Guidance, 1-1-10; Design Information, 1-1-20; and Design Document Requirements, 1-1-30. EXCEPTION to the format: In the case of design policies in Chapter 1 they are organized as follows: Policies, 1-1-00; Procedures, 1-1-10; Information, 1-1-20; and Reporting Requirements, 1-1-30.

3. Exhibits to sections of this manual are numbered by placing an "X" before the section number and placing the exhibit letter immediately after the section number. As an example, Exhibit B to Section 1-2 would be numbered Exhibit X1-2-B.

## B. How to Use the Design Requirements Manual

The DRM is compiled for use by all divisions within the Office of Research Facilities Development and Operations (ORF) and the A/E's designing laboratory and animal research facilities for NIH. The DRM is organized by discipline. The Division of Technical Resources (DTR) may be contacted through the Project Officer for clarification of any particular requirement within the DRM. The appendices include code references, design resources, checklists, forms, and general information that will assist in developing complete designs.

For ease of reference, portions of the DRM are interlinked within the body of the document. Other helpful references provided throughout the DRM are hot-linked to Web sites, including those found in the Appendices. The A/E shall contact the Project Officer for technical information requirements or coordination with the appropriate personnel within NIH for technical information required to complete a project.

## C. Maintenance

1. The Standards and Policy Branch (SPB), DTR, ORF is responsible for the maintenance of this manual.
2. Changes to the NIH Design Requirements Manual will be issued by the SPB.
3. Users of this manual are encouraged to submit proposed corrections, updates, and improvements to the Standards and Policy Branch for consideration.
4. It is the Policy Branch's standard practice to solicit input on proposed changes from affected parties prior to publishing a change to the manual.

## D. Distribution

1. The NIH Design Requirements Manual will be made available to each Office of Research Facility Development and Operation (ORF) Project Officer, Contracting Officer, and design contractor responsible for planning and design of NIH laboratories and vivariums. Compliance with NIH design guidelines and requirements outlined in the manual is the responsibility of each NIH Contracting Officer, Project Officer and design contrac-

tor. Appropriate distribution to the design contractors shall be assured by the Contracting Officer.

2. The manual will also be updated and posted on the ORF Web site http://orf.od.nih.gov

### E. Effective Date

This manual is effective August 27, 2008. Changes to the manual will be forwarded with an ORF Issuance Notice. The date of the NIH Design Requirements Manual Issuance Notice shown at the top of each page of each chapter/section shall be the effective date of the change.

## 1-1-10 Procedures

### A. Application

The NIH DRM establishes policy, design requirements and standards, and technical criteria for use in planning, programming, and designing of new NIH owned biomedical laboratories and animal research facilities and new additions to existing biomedical laboratories and animal research facilities.

### B. Facility Acquisitions

Facility acquisitions include the purchase and/or lease of existing structures or facilities by the federal government. For owned facilities, the A/E shall determine during early planning, what NIH life expectancy projections are for the particular facility and design to that expectation. Any proposed existing facility shall be evaluated prior to entering into a purchase or lease agreement for its capability to comply with the DRM. A determination shall be made for which elements of the DRM apply to the project based on the length of the lease.

### C. Application of the DRM to Renovations

Application of the DRM to renovations shall be as required in the A/E contract. A general conformance requirement in an A/E contract shall be interpreted as follows:

- Renovation that results in having an impact over 50% of the building area be in compliance with to the DRM.
- A full building gut renovation design shall be in complete conformance to the DRM.

### D. Requirements by Reference:

The appendices list reference documents that shall be used in conjunction with the DRM. All A/E work prepared for NIH shall conform to all requirements and recommendations of the reference documents except where the written text of the DRM states other-wise. For reference documents that are written as regulations, codes, or standards, all A/E work shall

be in conformance as if the reference document were the written text of the DRM. For reference documents that are written as handbooks, recommendations or manuals, the reference document shall be used as described in the DRM or where not described in the DRM, the 'best practice' methods recommended in the document shall be used.

# 1-1-20 Information

## A. Guiding Principles from the HHS Facilities Program Manual as they relate to the NIH Design Requirements Manual

Investment decisions with regard to agency real property assets need to be integrated with and supportive of core mission activities to effectively manage and optimize real property assets. To facilitate integrating real property asset management decisions with the agency mission requires two elements – a clear under-standing of the agency's mission that drives the allocation and use of all available resources (human capital, physical capital, financial capital and technology/information capital) and an effective decision-making framework. HHS facilities shall be planned and delivered to best meet the functional, safety, and environmental needs of the programs and missions they house.

- Environmental and Functional Needs: HHS buildings shall provide an environment in which occupants can perform their work with maximum efficiency at the optimum level of comfort. Real Property Management decision-making will support agency missions and strategic goals. Appropriate levels of investment will be made in real property assets to advance customer satisfaction.
- Safety, Health and Security: HHS buildings shall provide an environment that is safe and healthy for occupants, and that, to the greatest extent possible, offers them maximum protection during emergencies or disasters.
- Economy: HHS facilities shall be planned and delivered at the most reasonable cost in terms of combined initial and long-term expenditures, without compromising other mission requirements. HHS will accurately inventory and describe all of its assets in order that full and appropriate utilization of space can be promoted. Life-cycle cost-benefit analysis shall be employed to explore alternatives for satisfying new requirements. HHS will dispose of unneeded assets.
- Conservation and Resources: Energy and water conservation shall be given prime consideration in the planning and delivery of HHS facilities. Products, materials, and systems shall be selected with a view toward maximizing the use of renewable resources.
- Preservation of historic and cultural resources shall be given full consideration in planning and delivery of HHS controlled real property assets and federally assisted undertakings.
- Sustainable Design: The planning, acquiring, siting, designing, building, operating and maintaining of HHS facilities shall take into consideration sustainable design principles

including integrated design, energy performance, water conservation, indoor environmental quality and materials.

## B. Compliance with Codes and Standards

In accordance with Section 3-4 of the HHS Facilities Program Manual and 40 U.S.C. 3312 each NIH building shall be constructed or altered, to the maximum extent feasible, in compliance with one of the nationally recognized model building codes and with other nationally recognized codes including mechanical and electrical codes, fire and life safety codes, and plumbing codes. Due consideration shall be given to all State and local zoning laws as if the project were not being constructed or altered by a Federal agency. The Government and its contractors shall not be liable for the cost of issuing local building permits or performing inspections for NIH construction. The Contracting Officer shall insert a clause in every design and construction contract solicitation notifying prospective contractors of the statutory provisions of 40 U.S.C. 3112 (f) and (g).

The NIH main campus and headquarters is located in Bethesda, Maryland. The NIH has six field stations throughout the nation located in Poolesville, Maryland; Baltimore, Maryland; Hamilton, Montana; Research Triangle Park (RTP), North Carolina; Frederick, Maryland; and New Iberia, Louisiana. Geographical requirements, local government mandates, and other unique design criteria are not specifically mentioned in DRM since the design shall abide by state and local regulations. However, there are specific issues in a remote region that may be in conflict with the policies implemented by NIH in Bethesda, Maryland. If this occurs, the more stringent policy shall apply except as mandated by the applicable authority. The A/E is required to check for site specific requirements, starting with the regional Project Officer and/or regional director for remote NIH sites.

Specific requirements at RTP that deviate from criteria in the DRM include but are not limited to:

- Authority Having Jurisdiction (AHJ) for Fire Protection.
- County permitting.
- Interface with DOHS/ORF.

Specific requirements at Rocky Mountain Laboratories (RML) that deviate from criteria in the DRM include but are not limited to:

- Special bracing design in 2B seismic zone designation.
- 100% stand-by power versus load-shedding requirements.

- Special storm water management treatment due to gravel site.
- City-mandated special manhole requirements.
- City-mandated videotaping requirements.
- Unique traffic and noise standards.
- Historic Core.

### C. Biosafety Levels

Laboratories involving research with biological materials are classified into four biosafety level (BSL) categories (BSL1, BSL2, BSL3, and BSL4). These categories are outlined in detail in the Biosafety in Microbiological and Biomedical Laboratories (BMBL) issued by the CDC and NIH. Animal research facilities house animals in an appropriate species-specific environment that meets or exceeds all applicable policies, guidelines, and regulations as outlined in the Institute of Laboratory Animal Resources (ILAR) Guide for the Care and Use of Laboratory Animals (the "Guide"), BMBL, Public Health Service (PHS) policy, and Animal Welfare Regulations. In addition, laboratories shall meet the minimum requirements to be accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC). These facilities are classified into four animal biosafety level (ABSL) categories (ABSL1, ABSL2, ABSL3, and ABSL4).

BSL3/ABSL3 is referred to as "containment" and BSL4/ABSL4 is referred to as "high containment" biomedical laboratory and animal research facilities.

All laboratory and vivarium practices in NIH facilities, at a minimum shall meet BSL2 requirements. BMBL facility design requirements for laboratories operating at the BSL2 level require primary containment equipment such as BSCs autoclaves, bench top sink and pass through air. The ABSL2 animal facility requires autoclaves, hand washing sinks in the animal rooms and a mechanical cage washer. Division of Occupational Health and Safety (DOHS) along with research program officials shall approve the decision to design for biosafety levels higher than BSL2.

Placing Fume Hoods and Biological Safety Cabinets in laboratories shall comply with the findings of the "Methodology for Optimization of Laboratory Hood Containment - Volumes I and II, November 1996, Farhad Memarzadeh, PhD, P.E., NIH – Office of the Director, ORF Publication, Bethesda, MD"

## 1-1-30 Reporting Requirements

The DRM is a document that shall be used in Pre-Project Planning and reported and scored in the Project Definition Rating Index (PDRI) in accordance with Section 2-4 in Volume I of the HHS Facilities Program Manual.

# Section 1-2: Definitions



## 1-2-00 Policy

This section establishes definitions of terms used in this manual and NIH facility design programs. This section will assist users of the manual in understanding and properly applying certain terminology to the design process. These definitions and all other definitions in this Manual must be read consistently with all other similar relevant definitions set forth in any other potentially relevant and applicable laws, regulations and similar government-wide requirements.

The following terms are defined as they relate to the NIH Design Requirements Manual.

Adaptability - Adaptability is the ability to adjust to changing conditions or requirements under both normal and emergency conditions. One example would be that the Mechanical, Electrical and Plumbing (MEP) systems can accommodate changes in ventilation rate, temperature, and power.

Agency - In very general terms, an administrative unit of government. A Department Operating Division (OPDIV) is any of the agencies under the Department of Health and Human Services, which is responsible for the conception, planning, programming, budgeting, and/or execution of a program(s) and any associated operating functions.
Alterations – Improvements that consist of any betterment or change to an existing property to allow its use for a different purpose or function. See also the definition of “Improvements”.

Architect-Engineer Services (as defined in 40 USC 1102 and the FAR) -

A. Professional services of an architectural or engineering nature, as defined by State law, which are required to be performed or approved by a person licensed, registered, or certified to provide such services;
B. Professional services of an architectural or engineering nature performed by contract that are associated with research, planning, development, design, construction, alteration, or repair of real property; and
C. Such other professional services of an architectural or engineering nature, or incidental services, which members of the architectural and engineering professions

(and individuals in their employ) may logically or justifiably perform, including studies, investigations, surveying and mapping, tests, evaluations, consultations, comprehensive planning, program management, conceptual designs, plans and specifications, value engineering, construction phase services, soils engineering, drawing reviews, preparation of operating and maintenance manuals, and other related services.

As-Built Drawings - Construction drawings revised to show specific details changes made during the construction process, based on record drawings (marked-up prints, drawings and other data) furnished by the Con-tractor to the Government. The drawings shall clearly identify that they are the 'As-Built' drawings.

Basic Services: The services performed by an architect-engineer during the following five phases of a project: schematic design; design development; construction documents; bidding or negotiation; and contract administration.

Biosafety Levels: There are four biosafety levels which consist of combinations of laboratory practice and techniques, safety equipment, and laboratory facilities. Each combination is specifically appropriate for operations performed for the documented or suspected route of transmission of infectious agents.

Biosafety Level 1: Practices, safety equipment, and facility design and construction are appropriate for work with defined and characterize strains of viable microorganisms not known to cause disease in healthy adult humans.

Biosafety Level 2: Practices, safety equipment, and facility design and construction are appropriate for work with a broad spectrum of indigenous moderate risk agents that are present in the community and associated with human disease of varying severity.

Biosafety Level 3: Practices, safety equipment, and facility design and construction are appropriate for work with indigenous and exotic agents with a potential for respiratory transmission and which may cause serious and potentially lethal infection. At Biosafety Level 3 more emphasis is placed on primary and secondary barriers to protect personnel in contagious areas, the community, and the environment from exposure to potentially infectious aerosols.

Concepts - Drawings, sketches and/or graphics showing alternatives used to define a project's scope during the programmatic phase of the project.

Construction – The erection of a building, structure or facility, including the installation of equipment, site preparation, landscaping, associated roads, parking, environmental mitigation and utilities, which provides space not previously available. It includes freestanding structures, additional wings or floors, enclosed courtyards or entryways, and any other means to provide usable program space that did not previously exist (excluding temporary facilities). Construction projects are capitalized in accordance with the accounting principles of the Federal Accounting Standards Advisory Board (FASAB). See Section 2-1 of Volume I of the HHS Facilities Program Manual for additional information.

Containment Laboratory – This laboratory employs engineering controls for managing infectious materials in the laboratory environment where they are being handled or maintained. The purpose of containment is to reduce or eliminate exposure to laboratory workers, other persons and the outside environment to potentially hazardous agents. See Biosafety Level 3.

Containment Vivarium - The vivarium facility is to be designed to house animals infected with potentially lethal disease for the purpose of research at Biosafety Level 3.

Construction Codes – Any set of standards set forth in regulations, ordinances or statutory requirements of a local, state, or federal governmental unit relating to building construction and occupancy, adopted and administered enforced for the protection of the public health, safety and welfare, and the environment.

Construction Documents Phase – The third phase of the architect-engineer's basic services. In this phase the architect-engineer prepares from the approved design development documents, for approval by the Government, the working drawings and specifications and the necessary bidding information.

Construction Management - A professional service that applies effective management techniques to the planning, design, and construction of a project from inception to completion for the purpose of controlling time, cost and quality, as defined by the Construction Management Association of America (CMAA).

Construction Manager - A person, firm or business organization with the expertise and resources, who has the responsibilities under contract to the Government for coordination and accomplishment of overall project planning, design and construction.

Contract (as defined by FAR) – A mutually binding legal relationship obligating the seller to furnish the supplies or services (including construction) and the buyer to pay for them. It includes all types of commitments that obligate the Government to an expenditure of appro-

priated funds and that, except as otherwise authorized (by the FAR), are in writing. In addition to bilateral instruments, contracts include (but are not limited to) awards and notices of awards; job orders or task letters issued under basic ordering agreements; letter contracts; orders, such as purchase orders, under which the contract becomes effective by written acceptance or performance; and bilateral contract modifications.

Contract Documents - Those documents that comprise a contract, e.g., in a construction contract, the government contractor agreement (Standard Form 252, General Provisions and Clauses, Special Contract Requirements, other provisions in the Uniform Contract Format, specifications, plans and/or drawings, all addenda, modifications, and changes thereto, together with any other items stipulated as being specifically included.)

Contracting Officer - An individual who has the authority to execute a contract on behalf of the Government of the United States of America. This individual is the sole authorized agent in dealing with the contractor. The Contracting Officer has authority to negotiate and execute contracts on behalf of the Government and to make changes, amendments, approve payments, terminate contracts, and close out contracts upon satisfactory completion.

Contracting Officer's Technical Representative (COTR) –The Project Officer or other authorized representative that is designated by the Contracting Officer.

Contractor - The person, firm, or corporation with whom the Government has executed a contract, that is responsible for performing the work.

Cost-Benefit/Cost Effectiveness Analysis – Cost-Benefit/Cost Effectiveness Analysis is a mechanism to determine the best solution to satisfy facility requirements by exploring and comparing the economics of alternatives such as leasing, constructing a new facility, renovating an existing structure or an addition/alteration option.

Decontamination - The removal of biological agents by disinfection or autoclaving; the neutralizing and cleaning-out of acid and corrosive materials; and the removal, destruction, or neutralizing of toxic, hazardous or infectious substances.

Design-Bid-Build (as defined by FAR) - The traditional delivery method where design and construction are sequential and contracted for separately with two contracts and two contractors.

Design-Build (as defined by FAR) - Combines design and construction in a single contract with one contractor.

Durability - Durability is the ability to resist weathering, chemical attack, abrasion, impact, and other conditions of ordinary service for a cost effective life span or expected use, while having the quality of enduring maintenance such as washing and sanitizing with appropriate cleansers. Life expectancy, expected use, and life cycle costs will vary depending on the type of facility; the geographic location; and whether the facility is owned or leased and these other factors maintenance, material, and equipment quality.

Expandability - Expandability is the ability to enlarge at minimal cost. Expandability refers to expanding within set boundaries of a facility by demounting walls or by expanding the building footprint.

Facility - A building or group of buildings, a structure, utility system, the site and/or environs associated with the above.

Facility Project Budget – A summary of all anticipated project costs necessary for a construction, improvement or repair project to complete planning, design, construction, and activation including equipment and result in a fully operational facility . The source(s) of funding shall be identified in the project's budget. The facility project budget is documented on the HHS Form 300, Facility Project Approval Agreement.

Facility Project Approval Agreement (FPAA - HHS Form 300) - A written agreement between designated OPDIV officials (i.e., Project Manager, Project Director and OPDIV Board Member) and the Department evidencing the OPDIV's commitment to execute a particular project. A FPAA is required for all facility construction and improvement projects exceeding $1 million and all repair projects exceeding $3 million. The FPAA documents the project's scope and description, basis of need, funding source(s), and total cost from all sources. It identifies project schedule milestones, including completion of design, construction, activation and operational phases.

Fast Track Construction - A scheduling process in which design and construction activities overlap. Design documents and equipment and trade subcontracts are released incrementally or in phases.

Federal Acquisition Regulation (FAR) – The basic policy governing federal agency acquisitions. The FAR contains legal requirements, regulations, and policies that bear on contracting. The FAR is available electronically via the internet at http://farsite.hill.af.mil/vffara.htm or http://www.acquisition.gov/comp/far/index.html. There are many other useful websites available for FAR research that also includes agency specific supplements to the FAR.

Federal Agency (as defined by Federal Management Regulations [FMR]) – Any executive agency or any establishment in the legislative or judicial branch of the Government (except the Senate, the House of Representatives, and the Architect of the Capitol and any activities under that person's direction).

Federal Government Real Property Services Provider - Any federal government entity operating under, or subject to, the authorities of the Administrator of General Services, that provides real property services to federal agencies. This definition also includes private sector firms under contract with federal agencies that deliver real property services to federal agencies. This definition excludes any entity operating under, or subject to, authorities other than those of the Administrator of General Services.

Flexibility - Flexibility allows multiple choices or will accommodate future program changes. Flexibility includes adaptability, versatility, interchangeability and expandability.

General Services Administration (GSA) - Acting by or through the Administrator of General Services, or a designated official to whom functions under this part have been delegated by the Administrator of General Services.

Gross Area - The total square footage/square meters in a building for all floors from the outside face of exterior walls, disregarding such architectural projections as cornices, buttresses, and roof overhangs. Gross area includes all research and administrative space, retail space, and other areas such as vending machine space and storage. Gross area also includes major vertical penetrations such as shafts, elevators, stairs, or atrium space. This figure is used in defining construction costs for facilities. See Section 2-7 Volume I of the HHS Facilities Program Manual for additional information.

Historic Properties - Properties listed on the National Register of Historic Places or determined by the Federal Preservation Officer in consultation with the cognizant State Historic Preservation Officer (SHPO) or Tribal Historic Preservation Officer (THPO) to be eligible for listing on the National Register of Historic Places based on National Register Criteria.

Holding Agency - The executive agency that has accountability for the property involved.

Improvements (Renovations/Alterations) - Any betterment or change to an existing property to allow its continued or more efficient use within its designated purpose (Renovation), or for use for a different purpose or function (Alteration). Building improvements also include improvements to or upgrading of primary mechanical, electrical, or other building systems, and site improvements not associated with construction projects. Improvements typically increase the useful life of a facility and are capitalized against the existing property in accor-

dance with the accounting principles of the FASAB. See Section 2-1 Volume I of the HHS Facilities Program Manual for additional information.

Interchangeability - The ability to change or replace components with something else

Laboratory - Buildings used directly in basic or applied research in the sciences (including medicine) and in engineering, such as medical laboratories, meteorological research laboratories; and buildings used in designing, developing and testing prototypes and processes for chemistry and physics. This category excludes medical and industrial laboratories used for routine testing.

Landholding Agency - The federal agency that has accountability for the property involved. For the purposes of this definition, accountability means that the federal agency reports the real property on its financial statements and inventory records

Lease – Specific rights to real property that have been assigned to the Federal Government for a defined period of time. A federal lease is both a conveyance and contract to possess and use real property for a pre-determined period of time.

Life Cycle Cost - The total cost of owning, operating, and maintaining a building over its useful life, including its fuel and energy costs, determined on the basis of a systematic evaluation and comparison of alternative building systems; except that in the case of leased buildings, the life cycle cost shall be calculated over the effective remaining term of the lease.

Model Building Codes - Regional building codes adopted as law by local jurisdictions.

Nationally Recognized Standards - Encompasses any standard or modification thereof which:

A. Has been adopted and promulgated by a nationally recognized standards-producing organization under procedures whereby those interested and affected by it have reached substantial agreement on its adoption, or
B. Was formulated through consultation by appropriate federal agencies in a manner, which afforded an opportunity for diverse views to be considered.

Net Area/Net Space - Net Area or Net Space, refers to those portions of the facility available to use for program operations and for supply storage, building maintenance/operation, and other necessary support functions. Net Area is measured from the inside of the permanent exterior wall to the near side of permanent walls separating the area from stairwells, elevators, mechanical rooms, permanent corridors, or other portions of the building not catego-

rized as Net Space Area in the program of requirements document. In calculating net area, no deduction is made for columns and projections that are necessary to the building. However, deductions shall be made for large duct and elevator shafts passing through it. See Section 2-7 for additional information.

Net Assignable Square Footage - The area of a floor or office suite that is suitable for occupancy including secondary corridors. It excludes common or shared space that cannot be reasonably assigned for program purposes such as main egress corridors, hazardous waste marshaling areas on the loading dock, and other non-programmable space.

Office - Buildings primarily used for office space.

OPDIV Facilities Manager - The person in each HHS Operating Division, responsible for managing the OPDIV's facilities program (i.e. Director, Office of Research Facilities Development and Operations).

Owned – The Federal Government has fee simple interest in the real property

Pre-Project Planning - Process for developing sufficient strategic information through which HHS land-holding OPDIVs can address risk and determine required resources for successful construction projects.

Program Justification Document (PJD) - One of the planning and programming documents that the OPDIV may develop for obtaining approval for the project and its scope, for identifying potential environmental impacts, and for developing a cost estimate for inclusion in the HHS budget. Generally, the PJD includes an Introduction, General Overview, Space and Occupancy Summary, Staffing Summary, and an Executive Summary. To form a Program of Requirements (POR), technical requirements are attached to the PJD.

Program of Requirements (POR) - One of the planning and programming documents that the OPDIV may develop that describes the proposed facility. It includes estimates of design and construction costs, space requirements, environmental requirements, and other program information. Although normally developed by the program OPDIV, resource availability and time constraints may dictate that the POR be developed by a private A/E firm. Additional requirements for the POR are found in Chapter 2.

Project Definition Rating Index (PDRI) - A pre-project planning tool developed by the Construction Industry Institute (CII) that measures how complete the project scope has been defined. The PDRI score is required as part of the submission of OPDIV Facility Project Approval Agreements (HHS-300).

Project Officer - The government representative legally designated by the Contracting Officer as the authorized technical representative for administering A/E, construction and/or service contracts on behalf of the Contracting Officer, exclusive of contractual matters. The Project Officer is not authorized to issue any instructions or directions which affect any increases or decreases in the scope of work or which would result in the increase or decrease of the cost of the contract or a change in performance period of the contract.

Public Area - Any area of a building, which is ordinarily open to members of the public, including lobbies, courtyards, auditoriums, meeting rooms, and other such areas not assigned to a lessee or occupant agency.

Public Body - Any State of the United States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, or any political subdivision, agency, or instrumentality of the foregoing.

Real Property - Any interest in land (together with the improvements, structures, and fixtures located thereon) under control of any federal agency, except the public domain, or lands reserved or dedicated for national forest or national park purposes.

Record drawings – The drawings submitted by a contractor or subcontractor at any tier to show the construction of a particular structure or work as actually completed under the contract.

Renovation – Improvements that consist of any betterments or changes to an existing property to allow it's continued or more efficient use within its designated purpose. See also the definition of "Improvements."

Rentable Area – The (square footage) for which rent can be charged. Generally it is the gross area of the full floor less the area of all vertical penetrations (elevator shafts, stairwells, mechanical shafts etc.) Rentable area can be measured in many ways, but the most common measurement for office buildings is according to Building Owners and Managers Association (BOMA) standards.

Schematic Phase - The first phase of the architect-engineer's basic services. In this phase, the architect-engineer prepares schematics consisting of drawings and other documents illustrating the scale and relationship of project components for approval by the Government. The architect-engineer also submits to the Government a statement of probable construction cost.

Scope of Work (sometimes, referred to as 'Scope') – The narrative description of a project including the physical size and characteristics, functions, and special features.

Stakeholders - Individuals and organizations who are involved in or may be affected by the undertaking.

Standards – Something considered by an authority or by general consent as a basis of comparison; an approved model. Standards tell the user how something is commonly done and are usually regarded only as recommendations that do not have the force of law. Nationally recognized standards are frequently collected as reference information when codes are being prepared. In many instances, entire sections of the standards are adopted into the regulated codes by reference, and then be-come legally enforceable.

Statement of Work - The Statement of Work is a document in the acquisition process that describes the work to be performed or the services to be rendered, defines the respective responsibilities of the Government and the contractor, and provides an objective measure so that both government and the contractor will know when the work is complete and payment is justified. Common elements of the Statement of Work are Background, Project Objectives, Scope of Work, Detailed Technical Requirements, Deliverables, Reporting, Schedule, Special Considerations, and References.

Usable Square footage – (Also referred to as "office area".) The secured area (square footage) occupied exclusively by tenant within a tenant's leased space. The useable area times the load factor for common area results in rentable area on which rent is charged. Useable area can be measured in many ways, but the most common measurement for office buildings is according to BOMA standards. It does not include restrooms, elevator shafts, fire escapes, stairwells, electrical and mechanical rooms, janitorial rooms, elevator lobbies, or public corridors (for example, a corridor leading from the elevator lobby to the entrance of a tenant's office).

Versatility - Versatility is the ability to rearrange items within a space. For example, use of modular components within a lab or animal facility allows for relatively easy change out if there is a program change.

# Section 1-3: Abbreviations and Acronyms

1-3- 00 Policy (Reserved)
10 Procedures (Reserved)
20 Information
30 Reporting Requirements (Reserved)

## 1-3-00 Information

The following list of abbreviations and acronyms is provided for the benefit of the reader.

| | |
|---|---|
| A/D | Analog to Digital |
| A/E | Architect and Engineer |
| AAALAC | Association for Assessment and Accreditation of Laboratory Animal Care |
| ABA | Architectural Barriers Act |
| ABSL | Animal Biosafety Level |
| AC | Alternating Current |
| ACH | Air Changes per Hour |
| ACI | American Concrete Institute |
| ADA | American with Disabilities Act |
| AFF | Above Finish Floor |
| AHJ | Authority Having Jurisdiction |
| AHU | Air Handling Unit |
| AI | Analog Input |
| AIA | American Institute of Architects |
| ACI | American Concrete Institute |
| AISC | American Institute of Steel Construction |
| AM | As Manufactured |
| AMCA | Air Movement and Control Association |
| ANSI | American National Standards Institute |
| AO | Analog Output |
| APR | Air Pressure Resistant |
| APs | Access Points |
| ASCE | American Society of Civil Engineers |
| ASHRAE | American Society of Heating, Refrigerating, and Air-Conditioning Engineers |
| ASME | American Society of Mechanical Engineers |
| ASPE | American Society of Plumbing Engineers |
| ASSE | American Society of Sanitary Engineering |
| ASTM | American Society for Testing and Materials |
| ATC | Automatic Temperature Control |
| ATS | Automatic Transfer Switch |
| AV | Audio Visual |
| AWG | American Wire Gauge (Gage) |
| AWG | Average Water Gauge; American Welding Society; Animal-watering System |
| AWWA | American Water Works Association |
| BAS | Building Automation System |
| B&F | Building and Facilities |
| BCP | Breaker Control Panel |
| BFP | Backflow Prevention |
| BI | Binary Input |
| bit | Binary Digit |
| BMBL | Biosafety In Microbiological And Biomedical Laboratories |
| BO | Binary Output |
| BOCA | Building Officials and Code Administrators, International |
| BOMA | Building Owners and Managers Association |
| BSC | Biological Safety Cabinet |
| BSL | Biosafety Level |
| CADD | Computer-aided Design and Drafting |
| CAN | Common Accounting Number |
| CAT | Computed Tomography |
| CAV | Constant Air Volume |
| CBM | Certified Ballast Manufacturers Association |

CCC Clinical Center Complex
CDC Centers for Disease Control and Prevention
CD-ROM Compact Disk Read Only Memory
CEE Central Elevator Electronics
CG Compressed Gas
CGA Compressed Gas Association
CHW Chilled Water
CIT Center for Information Technology
CMU concrete masonry units
CNG Compressed Natural Gas
CO Contracting Officer
$CO^2$ Carbon Dioxide
COTR Contracting Officer's Technical Representative
CPF Controlled Permeability Form
CPS Cycles per Second (Hertz)
CPT Control Power Transformer
CQM Construction Quality Management
CRF Capital Recovery Factor
CRI Color Rendering Index
CRSI Concrete Reinforcing Steel Institute
CSI Construction Specification Institutes
CSA/CD Carrier Sense Access/Collision Detect(ion)
CT Current Transformer
CTIVS Collaborative Technology Innovation and Video Services Group
CW Cold Water
Cx Commissioning

D&T Diagnostic and Treatment
DC Direct Current
DCPM Division of Capital Project Management
DDC Distributive Digital Control
DDS Distribution Duct System
DEP Division of Environmental Protection
DFM Division of Fire Marshal
DFP Division of Facilities Planning
DGR Dedicated Ground Riser
DIL Dynamic Insertion Loss
DISS Diameter Index Safety System
DNA Deoxyribonucleic Acid
DNST Division of Network Systems and Telecommunications
DOE Department of Energy
DOHS Division of Occupational Health and Safety
DOT Department of Transportation
DPM Division of Property Management
DPSAC Division of Personnel Security and Access Control
DPSM Division of Physical Security Management
DRM Design Requirements Manual for Biomedical Laboratories and Animal Research Facilities
DRS Division of Radiation Safety
DSEIS Division of Scientific Equipment and Instrumentation Services
DTR Division of Technical Resources
DVD Digital Versatile Disc (formerly digital video disc)
DWV Drain Waste Vent

EIA Electronic Industries Association
ECB Environmental Compliance Branch
EDP Electronic Data Processing
EDDP Emergency Diesel Distribution Panel
EDS Emergency Distribution Panel
EF Exhaust Fan
EM Electron Microscope
EMC Electrical Metal Conduit
EMI Electromagnetic Interference
EMO External Manual Operator
EMR Elevator Machine Room
EMT Electric Metallic Tubing
EPA Environment Protection Agency
EPR Ethylene-Propylene Rubber
ERP Effective Radiated Power
ESRS Electron Spin Resonance Spectroscopy
ETL Electronic Testing Laboratory
EtO Ethylene Oxide

FACS Fluorescence-Activated Cell Sorter
FAR Federal Acquisition Regulations
FCC Federal Communication Commission
FCP Forest Conservation Plan
FD Fire Department
FDA Food and Drug Administration
FF Floor Flatness
FFE Facilities Furniture and Equipment

| | |
|---|---|
| FL | Floor Levelness |
| FM | Fire Marshal |
| FMB | Facility Branch Manager |
| FMR | Federal Management Regulations |
| FOIA | Freedom of Information Act |
| FRPs | Fiberglass Reinforced Panels |
| FTE | Full-time Equivalent |
| GFCI | Ground Fault Circuit Interrupter |
| GFI | Grand Fault Interrupting |
| GSA | General Service Administration |
| GW | Grease Waste |
| GWB | Gypsum Wallboard |
| HEPA | High-Efficiency Particulate Air |
| Hg | Hydrargentum/hydrargyrion (Mercury) |
| HHS | U.S. Department of Health and Human Services |
| HID | Human Interface Devices; or High Intensity Discharge |
| HIR | Halogen Infrared |
| HOA | Hands-Off-Automatic |
| HVAC | Heating Ventilation and Air Conditioning |
| HW | Hot Water |
| HWR | Hot Water Recirculating |
| I/O | Input/Output |
| IAQ | Indoor Air Quality |
| IBC | International Building Codes |
| IC | Institute or Center |
| ICC | International Code Council |
| ICU | Intensive Care Unit |
| IDC | Initiating Device Circuits |
| IDF | Intermediate Distribution Frame |
| IEC | International Electro-technical Commission |
| IED | Intelligent Electronic Device |
| IEEE | The Institute of Electrical and Electronics Engineers Inc. |
| IESNA | Illuminating Engineering Society of North America |
| IETA | International Electrical Testing Association |
| IFC | Industry Foundation Classes |
| IMC | Intermediate Metal Conduit |
| IPM | Integrated Pest Management |
| ISC | Interagency Security Committee |
| KCMIL | Thousand Circular Mils |
| LA | Laboratory Air |
| L/s | Liters per Second |
| LAN | Local Area Network |
| LCD | Liquid Crystal Display |
| LED | Light-Emitting Diode |
| LOD | Limits of Disturbance |
| LP | Low Pressure |
| LPI | Lightning Protection Institute |
| LS | Limit Switch |
| LSC | Life Safety Code |
| LV | Laboratory Vacuum |
| LW | Laboratory Waste |
| MA | Medical Air |
| MBC | Modular Building Controller |
| MCB | Main Circuit Breaker |
| MCC | Motor Control Centers |
| MDE | Maryland Department of Environment |
| MDF | Main Distribution Frame |
| MEP | Mechanical/Electrical/Plumbing |
| MG | Medical Gas |
| MH | Metal Halide |
| MLO | Main Lugs Only |
| MOU | Memorandum of Understanding |
| MOV | Metal Oxide Varistor |
| MPW | Medical Pathologic Waste |
| MR | Magnetic Resonance |
| MRI | Magnetic Resonance Imaging |
| MS | Mass Spectrophotometry |
| MSDS | Manufacturer's Safety Data Sheet |
| MW | Molecular Weight |
| NAC | Notification Appliance Circuits |
| NC | Noise Criteria or Normally Closed (switch) |
| NEBB | National Environmental Balancing Bureau |
| NEC | National Electric Code |
| NEMA | National Electrical Manufacturers Association |
| NESC | National Electrical Safety Code |
| NFC | National Fire Codes |
| NETA | National Electrical Testing Association |
| NFPA | National Fire Protection Association |
| NHP | Non-Human Primates |

| | |
|---|---|
| NICET | National Institute for Certification in Engineering Technologies |
| NIH | National Institutes of Health |
| NIOSH | National Institute of Occupational Safety and Health |
| NIST | National Institutes of Standards and Technology |
| nm | Nanometer |
| NMR | Nuclear Magnetic Resonance |
| NO | Normally Open or Nitrous Oxide |
| NRC | Noise Reduction Coefficient |
| NSF | National Science Foundation; National Standards Format; Nuclear Storage Facility |
| NTP | Notice to Proceed |
| O&M | Operation and Maintenance |
| OA | Office of Acquisition |
| OD | Office of Director |
| ODBC | Open Database Connectivity |
| OLE DB | Object Linking and Embedding Data Base |
| OMAR | Office of Management Analysis and Review |
| OQM | Office of Quality Management |
| OR | Operating Room |
| ORFDO | Office of Research Facilities Development and Operations |
| ORS | Office of Research Services |
| OS&Y | Outside Stem and Yoke |
| OSHA | Occupational Safety and Health Act (or Administration) |
| OSI | Open System Interconnection |
| OSP | Outside Plant |
| Pa | Pascal (pressure) |
| PAQ | Perceived Air Quality |
| PAR | Post-anesthesia Recovery |
| PC | Personal Computer |
| PCB | Polychlorinated Biphenyl |
| PCR | Polymerase Chain Reaction |
| PEPCO | Potomac Electric Power Company |
| PET | Position Emission Tomography |
| PF | Power Factor |
| PFA | Perfluoroalkloxy |
| PHS | Public Health Service |
| PI | Principal Investigator or Pulsed Input |
| PILC | Paper Insulated Lead Covered |
| PIR | Passive Infrared |
| PIV | Post Indicator Valve |
| PLC | Programmable Logic Controller |
| PLF | Plastic Laminate-Faced |
| PO | Project Officer |
| POR | Program of Requirements |
| PPE | Personal Protection Equipment |
| ppm | Parts per Million |
| PRV | Pressure-reducing Valve |
| PSDR | Physical Security Design Requirements |
| psi | Pounds per Square Inch |
| PT | Potential Transformer |
| PTFE | Polytetrafluoroethylene |
| PTI | Post Tensioning Institute |
| PVC | Polyvinyl Chloride |
| PWL | Power Level |
| PWM | Pulse-Width-Modulated Output |
| QSM | Quality Systems Manual |
| R | Ratio or R-value |
| RC | Room Criteria |
| RCR | Room Cavity Ratio |
| Re | Reynolds Number |
| RF | Radio Frequency |
| RFI | Radio Frequency Interference |
| RGBHV | Red-Green-Blue-Horizontal-Vertical |
| RGS | Rigid Galvanized Steel |
| rh | Relative Humidity |
| RML | Rocky Mountain Laboratory |
| RO | Reverse Osmosis |
| ROM | Read Only Memory |
| RPZ | Reduced Pressure Zone |
| RTD | Resistant Temperature Device |
| RTP | Research Triangle Park |
| RTU | Remote Terminal Unit |
| s | Second (time) |
| SAMA | Scientific Apparatus Makers Association |
| SAN | Sanitary Waste |
| SAP | Substation Automation Platform |
| SCADA | Supervisory Control and Data Acquisition |
| SCR | Silicone-Controlled Rectifier |
| SCU | Stand-alone Control Unit |

| | |
|---|---|
| SD | Storm Drainage |
| SDR | Standard Dimension Ratio |
| SE | Service Entrance |
| SER | Security and Emergency Response Services |
| SFO | Solicitation for Offer |
| SHPO | State Historic Preservation Officer |
| SLC | Signaling Line Circuits |
| SM | Smoke |
| SMACNA | Sheet Metal and Air Conditioning Contractor's National Association |
| SMR | Surface Metal Raceway |
| SOG | Slab on Grade |
| SPECT | Single Photon Computerized Tomography |
| SPF | Specific Pathogen Free |
| sr | Steradian (solid angle) |
| STC | Sound Transmission Class |
| SYG | Strong Yellow Green |
| TAB | Testing and Balancing |
| T&B | Testing and Balancing |
| TEC | Terminal Equipment Controller |
| TFN | Thermoplastic fixture Wire Nylon Jacketed (UL) |
| TGB | Telecommunication Grounding Bus Bar |
| THD | Total Harmonic Distortion |
| THHN | Thermoplastic High Heat Resistant Nylon Coated |
| THW | Thermoplastic Heat and Water Resistant Insulated Wire (UL) |
| THWN | Thermoplastic Heat and Water Resistant Nylon Coated |
| TIA | Telecommunication Industries Association |
| TMGB | Telecommunications Main Grounding Bus Bar |
| TMMS | Thermal Manual Motor Starter |
| TVSS | Transient Voltage Surge Suppression |
| UCP | Unit Control Panel |
| UDF | Unit Directional Flow |
| UFAS | Uniform Federal Accessibility Standard |
| UFCO | Urban Forest Conservation Plan |
| UFCP | Up Front Control Panel |
| UL | Underwriters Laboratories |
| UOB | Utility Operation Branch |
| UPC | Universal Programmable Controller |
| UPS | Uninterruptible Power Supply |
| UPW | Uniform Present Worth |
| U/S | Ultrasonic |
| UTP | Unshielded Twisted Pair |
| UV | Ultraviolet |
| V | Volt |
| VA | Volt-ampere |
| VAV | Variable Air Volume |
| VCT | Vinyl Composition Tile |
| VFD | Variable Frequency Drive |
| VGA | Video Graphics Array |
| VHF | Very High Frequency |
| VMB | Veterinary Medicine Branch |
| VOC | Volatile Organic Compound |
| VPN | Virtual Private Network |
| VR | Ventilation Rate |
| VSD | Variable Speed Drive |
| VSI | Voltage-Source Inverter |
| W/ | With |
| WAN | Wireless Area Network |
| WAS | Wide Area Services |
| WHO | World Health Organization |
| WLAN | Wireless Local Area Network |
| WSSC | Washington Suburban Sanitary Commission |
| WXGA | Wide Extended Graphic Array |
| XGA | eXtended Graphics Array |
| XHHW | Cross Linked High Heat Water Resistant Insulated Wire (UL) |

# Section 1-4: Measurement of Space



## 1-4-00 Policy

### A. Metric Standards for New Construction:

All final drawings and specifications for new construction shall be expressed exclusively in metric units. The General Services Administration (GSA) Metric Design Guide (PBS-PQ260), latest edition, and the Metric Guide for Federal Construction, found at the following website http://www.wbdg.org/ccb/VA/VAMETRIC/guide.pdf shall be used for guidance on how drawings, specifications, and other elements of metric implementation are to be addressed.

### B. Renovations and Additions

1. All facility renovation and addition design projects shall be based on the measurement for which it was originally designed or constructed.
2. If the facility was designed in English all renovations and additions shall be in English units.
3. Metric units shall be used for buildings renovations and additions originally designed and constructed in metric units.

### C. Leases

All lease facility design projects shall use English units in accordance with ANSI/BOMA Z65.1.

## 1-4-30 Information

### A. Units of Measure

The following list of units of measure is provided for the benefit of the reader.

| | | | |
|---|---|---|---|
| % | Percent | “ | Inch |
| ˚ | Degrees | ± | Plus or Minus |
| ˚C | Degrees Celsius | ≤ | Less than or equal to |

| | |
|---|---|
| < | Less than |
| ≥ | Greater than or equal to |
| > | Greater than |
| °C | degrees Celsius |
| °K | degrees Kelvin |
| µ | Micro |
| µm/s | Micrometers per Second |
| A | ampere |
| C | Coulomb (electric charge) |
| cd | candela |
| cm | centimeter |
| cph | changes per hour |
| dB | decibel |
| dBa | Decibels Acoustic |
| dBm | Decibel (referenced to miliwatts) |
| g | gram |
| gpm | gallons per minute |
| h | hour |
| Hz | hertz |
| J | joule |
| kg | kilogram |
| kHz | kilohertz |
| kJ | kilojoule |
| kPa | kilopascal |
| kV | kilovolt |
| kVA | kilovolt-ampere |
| kW | kilowatt |
| kWh | kilowatt hour |
| L | liter |
| L/s | liters per second |
| LPM | liters per minute |
| LPW | lumens per watt |
| lux | lux (Illuminance) |
| m | meter |
| m/s | meters per second |
| $m^2$ | square meter |
| mA | milliampere |
| Mbs | megabits per second |
| MCM | thousand circular mils |
| min | minute |
| MJ | megajoule |
| MHz | megahertz |
| mL | milliliter |
| mm | millimeter |
| mm Hg | millimeters of mercury |
| mHz | milihertz |
| mol | mole |
| mRem | millirem |
| n | nano |
| N | Newton (force) |
| $nm^2$ | nanometer squared or net square meter |
| Pa | pascal |
| ppm | parts per million |
| rad | radian |
| rpm | revolutions per minute |
| s | second |
| V | volt |
| VA | volt-ampere |
| W | watt |
| Ω | Ohm (electric resistance) |

## A. Net Assignable Area (NAA):

Net Assignable Area is the subset of the net area which is assigned to an NIH IC as program area and which the IC has controls. NAA is measured and calculated the same as Net Area. It includes centrally managed conference rooms, cafes and suite corridors which provide internal circulation and are not the main egress corridor for the floor. Prorated shared space such as autoclave rooms, ice rooms, waste management marshalling, and storage, is also included. NAA excludes all interstitial space and common areas such as:

corridors, electrical rooms, elevator closets, housekeeping closets, LAN/telephone closets, lobbies, locker rooms, mechanical rooms, storage rooms, switch rooms, toilet rooms, trash rooms, utility closets, vestibules, electrical wire closets, as well as laboratory break rooms, loading docks, lactation rooms, and other shared building amenities.

## B Rentable Area (RA):

Rentable Area is calculated for a given IC by adding the IC's NAA and a percentage of the common areas based on the proportion of NAA the IC occupies in the building. This definition is used in charging rent. Rentable Area is measured the same as net area. It is calculated as the NAA, plus:

- The pro-rata share of common areas, such as public corridors, atrium usable floors, restrooms, break rooms, lobbies, LAN/telephone rooms, housekeeping closets, mechanical/electrical rooms, and loading docks.
- The pro-rata share of the NIH shared common spaces, which are excluded in the NAA.
- The pro-rata share of the mechanical space on interstitial floors.

The sum of all tenant's Rentable Areas should equal the entire gross area of the building's floor(s) after deductions have been made for any major vertical penetrations. Typical Efficiency Ratio of NAA versus RA:

- Research Space: NAA equal about 50% of RA.
- Administrative Space: NAA equal about 85% RA.

# Gross and Net Area Calculations

## A.1 Gross Area

The gross area includes the total floor area of all floors including basements, mezzanines, penthouses, mechanical, electrical, and communications spaces, and enclosed loading docks.

Gross area is measured from the exterior surfaces of all enclosing walls, except where the exterior wall surface overhangs the exterior window surface by 300 mm (1") or more. In this case, the gross area is measured from a point one-half the distance between the exterior plane of the window glazing and the outermost plane of the wall. Disregard architectural projections such as cornices and buttresses, and roof overhangs less than 300 mm (1"). The average distance from the floor to the ceiling is used to determine whether a floor area is included at 100% or 50% in the gross area.

All areas with a floor-to-ceiling height of 2,134 mm (7'-0") or greater are counted at 100%.

All areas with a floor-to-ceiling height less than 2,134 mm (7'-0'') are counted at one-half of the actual gross area, unless otherwise noted not to be included in the gross area. The following additional spaces are counted at one-half of the actual gross area:

- Exterior balconies and porches
- Covered, but not enclosed, walkways, passageways, ramps, and covered building entrances
- Exterior open stairs, whether covered or uncovered

The following areas are not counted in the gross area:

- Crawl spaces or any area with a floor-to-ceiling height of less than 1,220 mm (4'-0"). Crawl spaces in excess of 1,200 mm (4'-0") are not counted in the gross area providing the clear height is the result of the natural site terrain or foundation system. It is expected that the depth of footings, lack of interior finish, and so forth will support the position that this area is used for limited access only and for no other purpose. The height of crawl spaces is the distance between the surface of the concrete slab and the bottom of any framing members. It is expected that girders, pipes, or ducts may occasionally protrude below this height.

- Catwalks providing access to equipment

- Exterior, uncovered, unenclosed terraces, ramps, stoops, or pads
- Open courtyards and plazas
- Utility tunnels
- Cooling towers
- Unroofed exterior equipment enclosures
- Unfinished attics

Shaft-type elements are counted in the gross area for one floor only. These include:

- Atria
- Unenclosed floor openings
- Stairs
- Elevators, escalators, and dumbwaiters
- Mechanical and electrical shafts
- Other shafts connecting two or more floors

A.1.a Interstitial Distribution Space: Interstitial distribution space, an expansion of the space between the finished ceiling and the underneath side of the floor above used for utility distribution purposes (i.e., ducts, electrical and communications lines, and plumbing) only, is not included in the gross area calculation. Any floor area dedicated to equipment and which provides maintenance access (walk-on deck) within the interstitial distribution space is included in the gross area calculation at 100% regardless of the floor-to-ceiling height.

A.2 Net Area: The net floor area of a space refers to those portions of the facility available for use for program operations and other necessary support functions. These areas are specifically delineated in the Program of Requirements (e.g., a 12 net m² office, a 10 net m² outpatient examination room). The sizes of net areas represented on design drawings or actually constructed are measured from the interior surface of the walls that enclose the space. Exterior walls, interior partitions, columns, structural members, plumbing chases, and internal circulation space for other than individual occupancy are excluded from the net floor area.

# Section 1-5: Project Design Review



## 1-5-00 Policy

The purpose of this section is to provide general guidance to the OPDIVs (NIH) for reviewing projects during the design phase. This policy applies to federally-owned real property assets. See Volume 1 Section 4-3 of the HHS Facilities Program Manual

The NIH has the overall responsibility to provide Government oversight for the design of an NIH facility. The ORF and customer review and comment on the Architect/Engineers (A/E) design submittal is vital to the success of the project.

The A/E is contractually responsible to design the project within the specified scope, budget and schedule. This is not only a Government requirement, but it is a common practice within the industry. The NIH shall ensure that the A/E fulfills their contractual responsibility to deliver a design of the approved HHS facility within Scope, Budget and Schedule.

### A. Mandatory Requirements

Sub-Sections X-X-00 “Design Requirements” and X-X-30 Design Document Requirements cited in the NIH Design Requirements Manual are mandatory design or procedure requirements and require formally submitted, reviewed and approved variance for any deviation from the requirements.

### B. Guidance and Information

Sub-Sections X-X-10 Design Guidance and X-X-20 Design Information cited in the NIH Design Requirements Manual are based on the collective knowledge gathered over the last 25 years in the design and construction of NIH biomedical research facilities and best practices learned from other institutions. The A/E is strongly encouraged and advised to follow the design guidance and information provided in these sub-sections. The A/E shall show cause in writing for the record as to any deviation from these sub-sections.

# 1-5-10 Procedures

The NIH determines the number of design submittals based on size and complexity of the project. The Project Officer (PO) holds and chairs design review meetings with technical and program review staffs at each specified design submittal stage. The A/E and the PO shall certify that the Project is within the Scope, Schedule and Budget per the approved FPPA at each submittal. If a submittal is found to be deficient and does not meet contractual obligations, the Government must reject the submittal. The A/E will revise and resubmit the submittal at no additional cost to the Government, and with no schedule extension in the overall project.

## A. Variance Request Procedures

The DRM provides quality standards that are performance oriented to the greatest extent possible to obtain a desired result. Prescriptive limitations, when given, such as exact dimensions or quantities, describe a condition that is commonly recognized as a practical standard or NIH requirement for effective operation. The provisions of this manual are not intended to prohibit the use of alternative systems, methods, or devices that are not specifically outlined in the document, provided that the proposed alternative design is at least equivalent or superior to the requirements in this manual with regard to such items as quality, strength, durability, effectiveness, fire resistance, health and safety, etc., and is approved by DTR.

During the course of programming and design development, it may become necessary for Project Officers and A/E to request variances from the established minimum standards. These variances may be necessary to accommodate existing building constraints or site conditions, required technology, or the Program of Requirements. Variance Request Forms are available in Exhibit X1-5-A “Variance Request Form.” Requests for variances shall be submitted by the A/E through the Project Officer following these specific procedures:

- Variances that are completed and submitted in accordance with the NIH QSM will be reviewed by DTR staff. This ensures that all variations to the DRM can be reviewed at one time to preclude conflicts in guidance.
- Packages requesting variances that meet the prescribed criteria will be considered for review by DTR. If the submittal is incomplete, or requires resubmission, additional time may be required for the review. Submissions based on future variances approvals are at the A/E’s risk. Warning: Variance submission does not guarantee variance acceptance. The Project Officer shall provide the A/E with the requirements necessary for submittal.

- Following submittal of a complete package by the Project Officer to DPPA, the review will take a minimum of 10 working days. Additional time may be necessary depending on the complexity of the request, coordination with other requests, or resubmission due to incomplete documentation. This timeframe shall be considered by the A/E team when developing the overall project development schedule.
- All known variances shall be submitted before the completion of the design development stage (35%) for a project. In some cases, the need for a variance may become apparent as the result of work done after the design development stage. Only in these cases will late variances be considered.

# 1-5-20 Guidance and Information

## A. Roles and Responsibilities

### A.1 Architect/Engineer

The A/E shall submit completed progress designs in accordance with their contract to the Government for review and comment. The NIH shall require the A/E to provide the following minimum milestone submittals for all projects with a cost of $ 5,000,000 or more:

1. Schematic Design
2. Design Development
3. Construction Documents

The A/E shall not proceed to the next phase of project design until written approval of the current submittal is received from the approval authority.

### A.2 Project Officer

The Project Officer (PO) serves as the Contracting Officer's Technical Representative (COTR). The PO leads, directs and controls the Government's activities as they relate to the design review of an HHS facility. The PO is the focal point for the Government and as the COTR, the PO serves as the Government's authorized representative with respect to communicating and distributing comments to the A/E. The PO holds and chairs design review meetings with OPDIV program and technical staff to evaluate design review comments. The PO determines if the review comments are within the scope of the A/E's contract. If comments are not within the scope, the PO will reject the comments and does not forward them to the A/E.

## A.3 NIH Technical Review Staff

The NIH utilizes select senior design discipline experts who have professional and technical experience in preparing contract documents to assist the PO in reviewing and evaluating the A/E's work. The technical review staff should be very familiar with the A/E scope and contract, and should be allowed to interact with the A/E when appropriate. Comments may include recommendations and suggestions to ensure the success of the project. Comments that are directives are to be avoided unless items within the design submittal are not in accordance with the scope of contract.

## A.4 NIH Program Staff

Care and deference must be given to NIH Program Staff as the end-users, customers, and clients. However, they are not the A/E's customer or client. The A/E's client is the Contracting Officer or the COTR acting as the CO's designated representative. NIH program staffs are generally not familiar with the A/E contract and their comments may be programmatic without consideration of A/E - Government contractual obligations. Care must be taken to ensure the NIH Program Staff's comments are within contract scope. The PO is the communications conduit between the program staff and the A/E.

**DIVISION OF TECHNICAL RESOURCES (DTR)**
**NIH DESIGN REQUIREMENTS PROJECT SPECIFIC**
# REQUEST FOR VARIANCE

Drawing Reference: _____

Detail Number: _____

Spec. Section Reference: _____

Paragraph # in Guidelines: _____

Campus On Off

To: **Gabor Konkoly-Thege** **(301) 496 - 1504**
Variance Coordinator, DTR, ORF Phone

From: _____
Project Officer Team Date

_____ _____ _____
A/E Name Phone Fax

_____ _____
Work Request Number Proposed Variance Subject

Yes No Type: _____
New Construction: e.g. lab, animal, office, BSL?

**(Variances should be requested during pre-design or early in the design phase.)**

Project Title _____ Estimated Construction Cost _____

Building Number _____ Project Percent Completed _____ %

Location _____ Other _____

Describe variance. State specifically how it deviates from the guidelines, how it improves the existing condition and the advantage to implementing. Provide hard copy supporting documents as necessary to variance coordinator:

Provide recommendation of discipline or disciplines to review variance; i.e. mechanical, electrical, architect, civil, structural, fire protection or other:

**PLEASE DO NOT FILL IN BELOW THIS LINE.**

DTR Routing:

DTR Response:

**Variance Number:** _____ Rev. 08/08

# Section 1-6: Project Cost Monitoring & Cost Control



## 1-6-00 Policy

The purpose of this section is to provide guidance to the OPDIVs (NIH) for monitoring project cost on federally owned real property assets. When construction funding is submitted to the Office of Management and Budget (OMB) for inclusion of the Department's budget, the maximum project budget is considered to be fixed and linked to project scope. Reducing scope to maintain budget limits is considered similar to a cost overrun. See Volume I Section 4-4 of the HHS Facilities Program Manual.

### A. Pre-Project Planning

The NIH shall ensure that the cost and scope of the project is locked into the budget and linked to the Pre-Project Planning and the Facilities Project Approval Agreement (FPAA). Pre-Project Planning must be completed prior to a construction budget submission to OMB and Congress. Once the construction budget is submitted to OMB and Congress, the NIH/HHS is committed to that budget and scope. Adequate Pre-Project-Planning must be done for assurance that the project can be delivered at full scope within the submitted budget. The Division of Facilities Planning provides leadership in the preparation of FPAAs.

### B. Programmatic Requirements

Once submitted to HHS and under A/E design, programmatic changes and other requirements (i.e. growth) must be held to an absolute minimum. The NIH must maintain control of its programmatic requirements.

## 1-6-10 Procedures

The NIH shall certify that the project is within scope, schedule and budget per the approved FPAA at each submittal. The A/E contract "Design within Funding" clause must be consistent with the approved FPAA. At a minimum the A/E should submit a broad order of magnitude estimate (square meter cost) at the schematic level, a systems estimate at design development level, and detailed quantity takeoff estimate at the contract document level.

If a submittal is found to be over the budget, the Government will reject the submittal. The A/E shall resubmit the submittal to bring it within the budget in accordance with the "Design within Funding" clause of his/her contract. The exceeded budget portion of the construction cost shall not be a basis for the A/E to claim additional fee against the Government.

## 1-6-20 Guidance and Information

### A. A/E

The A/E shall design the project within the budget and shall provide a construction cost estimate at each scheduled design submission. The A/E shall provide a narrative description of the methodology used in the development of the estimate. If estimating software is used to produce the estimate, provide summary details of the software.

### B. The Government Estimate

The final estimate will be considered the "Government Estimate" after it has been reviewed and accepted by the Contracting Officer. The final estimate shall be detailed including material, labor, and significant equipment costs for each line item. The final estimate shall not exceed the construction budget.

## 1-6-30 Reporting Requirements

With adequate level of Pre-Project-Planning prior to budget submission, scope changes and cost overruns should be rare occurrences. However, it is recognized that unexpected mission changes do occur that could not have been anticipated during the budget development, and that these mission changes can drive unexpected changes in the scope or budget of facility projects. OPDIVs are encouraged to avoid custom design and develop generic designs that are flexible and adaptable to deal with unexpected mission changes. In the event that an unexpected change in mission results in a change in scope or budget of the project, the OPDIV will immediately report these changes to Office for Facility Management and Policy (OFMP) and submit a revised FPAA per requirements outlined in Volume I Section 2-3 of the HHS Facilities Program Manual.

# Section 1-7: Commissioning



## 1-7-00 Policy

In accordance with HHS policy, NIH will develop, implement and maintain a commissioning procedure for all new and renovated facilities that meet or exceed the HHS Capital Investment Review Board threshold ($10M). The NIH may determine that other facilities should be commissioned based on the complexity and nature of the facility.

Commissioning is the process of making sure all building systems are working before occupants move in. It involves making sure all systems are: installed properly and perform according to design; cost effective; meet the users' needs; adequately documented and well understood by operators. Commissioning serves to accomplish the following goals:

- Reduced number of deficiencies at completion.
- Lower utility costs attributable to efficiently operating systems.
- Lower maintenance costs due to properly trained maintenance crew.
- Higher productivity of the building occupants because of properly balanced ventilation system.
- Design for maintainability.
- Reduced outages and downtimes due to better diagnosis of failures.
- Well documented and successful system tests.
- All building systems perform in accordance with the design requirements.

## 1-7-10 Procedures

### A. NIH Commissioning Philosophy and Requirements:

NIH requires Commissioning (Cx) for all projects. The level or scope of commissioning for any single project shall be determined by the complexity of the project. The NIH Model Commissioning Guide, to be published in 2011, will contain complete, detailed commissioning requirements. Commissioning is a comprehensive process for ensuring that:

- All building systems are installed and perform according to the design intent.
- Systems are efficient, cost effective and meet the user's operational needs.

- The installation is adequately documented.
- The operators are adequately trained.

The requirements in the NIH Model Commissioning Guide cover each phase of the project from the planning phase through warranty for all types and sizes of buildings, occupancies, and systems. They apply to new buildings, as well as renovations and expansions. NIH Cx requirements shall occur parallel to established conventions ensuring design and construction quality. Cx shall provide monitoring and review of these conventional processes, and add supplemental processes for additional assurance of optimal performance.

Cx entails coordinating the efforts of the various parties involved in the design, construction, use, and operation of a facility to achieve an optimal facility. It is more comprehensive than conventional construction phase quality control activities such as construction observation, start up, and testing, adjusting and balancing. NIH Cx focuses on the dynamic systems in the facility, such as the mechanical, electrical, plumbing, fire protection, and security systems. Although Cx is performed on some static systems, the need for Cx is more substantial on the dynamic systems. Other DRM requirements can often assure an adequate level of construction quality for the static elements.

The Cx activities shall be included in the project schedule. Effective planning and a strong commitment to maintenance of a detailed, integrated project schedule will shorten the impact Cx has on the project duration. Planning and budgeting for Cx shall begin at the onset of a project. A Government selected independent third party commissioning authority (CA) is required and shall be funded by the project. The CA facilitates and assists other parties in the Cx process but does not direct work or approve/accept materials, systems or equipment. The CA makes recommendations to the appropriate party who directs work, approves or disapproves work, etc. The scope and budget of development managers (DM), A/E's, construction managers, construction contractors and all other entities involved with the project will be impacted by Cx.

Maintenance, safety and institute personnel, and others will also be involved in the Cx and will need to plan adequate resources from the beginning of the process. Roles and responsibilities are outlined below. Although the NIH Model Commissioning Guide provides detailed roles and responsibilities of the individual members of the project team, it is important for the A/E to be aware of the roles and responsibilities of different parties involved in the Cx process.

## A.1 Cx Process during Different Project Phases:

The following information highlights some of the critical roles and responsibilities of different parties involved in the Cx process during different project phases. This is not a comprehensive list but only meant to make parties aware conceptually:

Programming Phase: During the programming phase, the project team, including facility users, outlines the functional requirements of the facility and documents the scope of Cx. Cx sequence shall include:

- Inclusion of Cx requirements in all project related contracts.
- Inclusion of credentials related to Cx in selection criteria.
- Inclusion of Cx in the project budget.
- Documentation of project requirements in a format that is transferable to the Cx documentation.

Conceptual Design Phase: During the conceptual design phase, the project team, including facility users, forms the basis of design (BOD) and room data sheets (RDS), and begins Facility Guide. Cx sequence shall include:

- CA appointment.
- CA development of the initial Cx Plan.
- CA review of the BOD and RDS, and participation in Facility Guide.

Schematic Phase: During the schematic phase, the concepts of the project are developed to the point of schematic and single line drawings. The Cx sequence shall include:

- Identification of the Cx team and onset of participation in the Cx process.
- CA performance of the following:
  - Conducts the Cx kick off meeting,
  - Reviews schematic designs and design criteria, and
  - Produces preliminary versions of Cx specification sections.
- Naming conventions to be used on project equipment established and or directed by operators.

Construction Documents Phase: During the construction documents phase, detailed design is accomplished and the contract documents are prepared for bidding. This phase may consist of multiple sub-phases. Cx sequence shall include:

- A/E response to all schematic phase comments, development of Systems Matrix in concert with developing the specification and submittal of draft specification electronically.

- Operators review and comment on Systems Matrix and other documents.
- CA development and completion of specifications on Cx requirements, completion of Cx plan and design phase version of the Facility Guide, review of other construction phase submittals, and development of a summary document that will track the Cx process.
- CA development of Cx precedent diagrams to reflect Cx tasks and how to most effectively sequence systems turn over to minimize the Cx impact on the schedule.
- CA development of the design phase version of the Facility Guide.
- A/E update of the BOD.
- A/E response to all design review comments including Cx comments.

Bidding Phase: During the bidding phase, installation or construction is competitively bid and contractors/subcontractors are selected. Cx sequence shall include technical support provided by CA.

Construction Phase: During the construction phase of the project, the facility is built. Systems and equipment are installed and started. Contractor provides submittals, does testing, etc. Contractor/Vendors conduct equipment specific training. Cx sequence shall include:

- Designation of a Cx Coordinator (CxC) by all major subcontractors and operators to represent them in the Cx process.
- Cx kick off meeting conducted by CA.
- Incorporation of Cx tasks in detailed project schedule and presentation of an updated schedule at each Cx progress meeting by the contractor.
- CA review and comment on shop drawings and other submittals, inspections and attendance of meetings, and production of detailed project specific pre-functional and functional testing procedures.
- Supplementation of the pre-functional procedures developed by CA with contractor-provided submittals, and contractor-provided training plan for review by CA and operators.
- CA and operators' review and approval of start up protocol.
- Submittals of Operations and Maintenance (O&M) portions of the Facility Guide and Temporary Conditioning Plan by the contractor for review by A/E, CA, and operators.
- Witnessing of close in inspections by operators, CA, and PO.
- Recordation of all nameplate data by the contractor.
- Training provided by the contractor.
- Design Intent and Systems Overview Training by the A/E with assistance from CA.

Acceptance Phase: During the acceptance phase, the facility and its systems and equipment are inspected, tested, etc. Most of the formal training occurs during this phase, generally occurring after the construction phase is complete. The A/E and contractor finalize

"as built" record documentation. Approved functional completion marks the end of this phase. Cx sequence shall include:

- Establishment of trending and monitoring as applicable for systems by the contractors.
- Spot check start-ups and balancing by CA and the operators.
- Functional Operational Systems Test (FOST) directed/conducted by CA, in which most parties also participate to some degree, primarily for initial samples. Continued activity with FOST performing repetitive samples by CA and operators.
- FOST documentation by CA, recommendations of acceptance as applicable, and update of FOST status on Cx summary document.
- Development and performance of commissioned systems training by CA.
- Completion of record documentation and submittal for approval by the contractor and A/E.
- Remedies issuance to issues that caused failure of FOST's and CA retests by the contractor.

Endurance Test Phase: During the endurance test phase, equipment is run continuously, monitored and trended. This phase is applicable to critical occupancies such as BSL-3, vivaria, data centers, and other areas as directed by the Project Officer. Cx sequence shall include:

- CA ensures monitoring is in place and functional throughout this period.
- Use the space by occupants to confirm functionality.
- Proper operation of the facility throughout this period.

Warranty Phase: The warranty phase includes the early occupancy of the building through the end of the warranty period, and at least into the opposite season from when it was initially tested. The contractor performs warranty service, corrects deficiencies, and finalizes record documentation to reflect actual conditions at the end of the warranty period. The operators work with the CA and the A/E to fine tune the facility to meet actual occupancy. Cx sequence shall include:

- Onset of warranty upon completion of the acceptance phase.
- Submittal of final Cx report by CA, and addition to Facility Guide important lessons learned, changes made, etc.
- Maintenance of log of warranty calls which tracks diagnosis and resolution by contractor.
- Operator initiated warranty calls, as necessary.
- Record documentation is updated, as necessary.
- Performance of opposite season testing by CA.
- Documentation of issues and problems with the facility by the operators.

- Occupants' use of the facility.

Renovations or modifications to the facility, if done, in conformance to the limitations dictated in the Facility Guide.

# Section 1-8: Value Engineering



## 1-8-00 Policy

This section describes NIH policy and procedures for value engineering (VE) in Architectural/Engineering (A/E) and construction contracts for federally-owned HHS real property assets. VE is mandatory for projects where the construction cost is $1 million or greater. (See OMB circular A-131.) All projects developed using Design-Build that are procured using full and open competition and are awarded based on a best value selection process are exempt from further VE. HHS requires an independent VE analysis by a specialized consultant or Government personnel for projects with a total project cost of $ 10 million or more.

The NIH designated Value Engineering Coordinator (VEC) coordinates NIH's VE activities. The VEC shall receive formal Society of American Value Engineering (SAVE) approved training in value engineering. The Contracting Officer, in consultation with the VEC, is responsible for determining which contracts are subject to VE and for accepting or rejecting VE proposals.

### A. Definitions

Life Cycle Cost (LCC) - The sum of all costs over the useful life of a building, system or product including the costs of design, construction, acquisition, operation, maintenance, repairs, disposal and salvage (resale) value, if any, using present worth costs. For evaluating proposed capital investment projects, the modes of analysis to be used include:

a. Total Life Cycle Costs
b. Net Savings
c. Saving-to-Investment Ratio
d. Payback Period
e. Internal Rate of Return

Value Engineering (VE) - The formal technique by which contractors may (1) voluntarily suggest methods for performing more economically and share in any resulting savings or (2) be required to establish a program to identify and submit to the Government methods for performing more economically without reduction in program requirements or quality. Value engineering attempts to eliminate anything that increases acquisition, operation, or support

costs, without impairing essential functions or characteristics. VE involves an organized effort to analyze alternative approaches for provision of systems, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life cycle cost consistent with required performance, reliability, quality, and safety.

Value Engineering Change Proposal (VECP) - A proposal developed by a construction contractor under a value engineering clause in its construction contract that typically involves sharing in any resulting savings. The proposal normally involves changes in the drawings and specifications directed at reducing the construction costs or life cycle costs without impairing the project's essential functions or characteristics.

Value Engineering Proposal (VEP) - As used in this section, a VEP in connection with an A/E design contract, is a proposal for change developed by the A/E design firm, employees of the Federal Government, or a specialized VE consulting firm. The proposal is similar to the VECP described above and is generally performed on a partially completed facility design. However, it is noted that there is no cost sharing of projected savings during the design phase.

Base Year - The base year is the first year of the Value Engineering study period.
Funds Invested - Estimates should include salaries and overhead expenses of value engineering, training costs for contracting for value engineering services, value engineering proposal development and implementation costs, and any other costs directly associated with the VE program.

Present Worth (PW) - The time-equivalent value of past, present, or future cash flows as of the beginning of the base year.
Net Savings - The net savings is the time-adjusted savings less time-adjusted costs taken over the study period.

## 1-8-10 Procedures

### A. Value Engineering in Design Contracts

General - Federal Acquisition Regulations (FAR) Part 48 requires the Contracting Officer to include a VE clause in solicitations and contracts for A/E services whenever the Government requires and pays for a specific VE effort in A/E contracts.

Projects Requiring HHS Capital Investment Review Board Approval and a total project cost of $ 10 Million or More - OPDIVs shall obtain independent VE analysis from a specialized

consultant or Government personnel. The specialized consultant must be an independent party from the project A/E.

Projects with a construction cost of $ 1 million or greater - NIH may accomplish value engineering through the A/E contractor, a specialized independent consultant, or Government personnel at the discretion of the VEC and the Contracting Officer. Regardless of who performs VE, the value engineering analysis shall be done at the end of schematic design phase or no later than the midpoint of the design development phase to be effective. In addition, the VE team shall include a certified value specialist team leader and A/E professionals with VE training and experience.

1. When projects meet the thresholds for VE, the VEC should proceed as follows:
   a. In conjunction with the Contracting Officer, determine the scope of VE analysis to be undertaken, considering the size and type of the project, and document to the contracting file.
   b. If being accomplished by Government personnel, appoint a VE team. The VE team shall consist of members with expertise in the areas or disciplines to be reviewed for the project.
   c. Upon completion of analysis, file a VE report.
   d. Maintain copies of VE proposals and supporting documentation in the contracting file.
2. The following information shall be included in each VEP whether done by the A/E, specialized consultant or Government personnel:
   a. Description and Comparison - A description of the difference between the existing and proposed design, the comparative advantages and disadvantages of each, a justification when an item's function is being altered, the effect of the change on system or facility performance, and any pertinent objective test data. This may include but is not limited to sketches, calculations, models, etc.
   b. Specifications - A list and analysis of design criteria or specifications that must be changed if the VEP is accepted.
   c. Project Cost Impact - A separate detailed estimate of the impact on project cost of each VEP, if accepted and implemented by the Government.
   d. Implementation Costs - A description and estimate of costs the Government may incur in implementing the VEP, such as design change cost and test and evaluation cost.
   e. Life Cycle Costs - A prediction of any effects the proposed changes may have on life cycle cost. Cost comparisons shall assume a 30-year building life.
   f. Schedule Impact - The effect the VEP will have on design or construction schedules.

## B. Value Engineering In Construction Contracts

General - FAR Part 48 requires the contracting officer to include a VE clause in construction solicitations and contracts when the contract amount is estimated to be $100,000 or more, unless an incentive contract is contemplated or the agency has granted an exemption. The Contracting Officer may include a VE clause in construction contracts of lesser value, if the Contracting Officer sees the potential for significant savings.

1. As a minimum each VECP submission from the contractor shall include the documentation required under FAR Part 48.
2. The OPDIV will review and objectively evaluate each VECP, and document the contract file with the rationale for acceptance or rejection of the VECP. If a VECP is accepted, the Government and the contractor shall share the savings, as prescribed in FAR Part 48.
3. The NIH is responsible for establishing guidelines for processing VECPs consistent with FAR Part 48 requirements.

# 1-8-20 Guidance and Information

The payment for VE services performed by non-governmental employees is an authorized expense of project design funds. These services must be separately priced in the A/E contract and are not included in the six percent fee limitation for the A/E design services. VE services will be quantified in terms of “level of effort” rather than as a deliverable.

Below is a list of the primary Federal regulations governing value engineering for HHS projects:

1. OMB Circular A-131, Value Engineering
2. FAR, Part 48
3. 10 CFR 436 subpart A - Life Cycle Cost methods and criteria contained in the Federal Energy Management Program (FEMP) rules.

# 3-8-30 Reporting Requirements

OMB Circular A-131, "Value Engineering," requires that NIH/HHS maintain data on the VE program. The VEC shall maintain records on the number of VECPs received from construction contractors, the number of VEPs prepared on design contracts and the amount of potential savings accepted by the Government within each of these categories. This information will be compiled and provided to the Division of Planning and Construction, OFMP, OS to fulfill the annual reporting requirements to the Office of Management and Budget

# Section 1-9: Environmental Management/Radiation Safety



## 1-9-00 Policy

This section describes the general requirements and specific goals for managing environmental issues on NIH campuses, including:

- Bulk storage facilities.
- Hazardous materials storage and handling.
- Hazardous waste storage and handling.
- Radiation safety.
- Solid waste management and recycling.
- Wastewater discharges.

Attention to environmental management issues and proper waste handling is a key element of the NIH overall goals of ensuring the health and well-being of NIH employees, visitors, and neighbors, and maintaining the NIH campus atmosphere.

The DRM requirements regarding environmental management on the NIH campus encompass the current federal and state of Maryland regulations regarding environmental management issues. They also include the requirements of local governments and agencies such as the WSSC and Montgomery County, Maryland. Federal laws applicable to environmental management on the NIH campus include:

- Clean Air Act.
- Clean Water Act.
- Hazardous Materials Transportation Act.
- National Environmental Policy Act.
- Resource Conservation and Recovery Act.
- Safe Drinking Water Act.
- Toxic Substances Control Act.
- Worker Safety Requirements.

Certain environmental issues have been excluded from this section of the DRM and addressed elsewhere. See Chapter 3: Civil Engineering & Site Development for storm water management, sediment control, erosion control, wetlands and use of fertilizers in landscaping. Refer to Section 1-10: Integrated Pest Management for use of pesticides. It is the goal of NIH to fully comply with all federal and state requirements in these areas.

Sediment and Erosion Control (SEC) drawings shall be prepared for all projects that result in ground disturbance. See Chapter 3: Civil Engineering & Site Development Section 3-1-20-B "Sediment and Erosion Control".

### A. National Environmental Policy Act (NEPA):

NEPA applies to all projects regardless of size. This is a joint process between the Project Officer, DEP, and DFP to determine the appropriate action. Based on a preliminary project description (scope), it may be possible to determine that no further action is necessary. Possible further actions include categorical exclusion, development of an Environmental Assessment (EA), or an Environmental Impact Statement (EIS). A flowchart of the NEPA process has been prepared and is maintained by DEP.

## 1-9-10 Procedures

All NIH facilities shall be designed to minimize the use of hazardous substances. The use of alternative non-hazardous or nontoxic materials is preferred in all new construction and renovations. The A/E shall develop a plan for eliminating the use of hazardous substances. Where hazardous substance use is unavoidable, the A/E shall demonstrate that alternate non-hazardous substances are either not available, inferior to the hazardous substance, or cost prohibitive. Examples of hazardous substances that shall be avoided include, but are not limited to: oil-based paints and caulks; hazardous cleaning, surface preparation, and paint-stripping solvents; and petroleum-based contact adhesives.

In general, most new construction will result in the release (off-gassing) of odors that can affect occupant comfort. If hazardous substances are avoided in construction, these odors will generally be nonhazardous; however, they can still have a detrimental effect on indoor air quality. Examples of nonhazardous substances that can affect indoor air quality include systems furniture, carpets, and latex paints.

New facilities shall be allowed to off-gas prior to occupancy. Ventilation systems of new construction shall be operated for a minimum of one month before the building is occupied. For renovations, where it is not feasible to isolate NIH employees from the off-gassing, ma-

terials that will off-gas and affect indoor air quality shall be allowed to air out and off-gas in a warehouse or in a well ventilated, unoccupied area before they are installed.

Insecticidal dusts, such as boric acid, shall not be applied in wall cavities, voids, and/or chase areas as part of the facility construction or renovation.

# 1-9-20 Guidance and Information

## A. References:

The A/E design firm shall use and comply with the design and safety guidelines, and references listed in Appendix A and cited throughout this chapter, as well as other safety guidelines received from the NIH Project Officer or as required by the program. The A/E shall utilize the latest editions of reference design and safety guidelines available at the time of the design contract award.

## B. Hazardous Substances Receiving, Storage, Staging Areas and General Handling:

### B.1 Receiving Areas:

Hazardous substances used at the NIH fall into two categories. They are either substances used in the facility directly for research activity such as laboratory chemicals used to perform analyses; or substances used in support of the facility such as chemicals used for washing glassware, cage washing, or neutralizing wastewater discharges.

Hazardous substances used in a laboratory are delivered directly to the end-user laboratory from the loading dock. Staging and temporary storage areas shall not be required in the receiving area for these materials.

Materials used in support of a facility must be placed in a hazardous-substance storage area. In general, these materials are received in 220 L drums or larger. Some neutralization chemicals may be stored in bulk containers up to 1,600 L. Storage capability shall be provided for up to ten drums. Buildings utilizing these hazardous substances shall be designed with a receiving and storage area located at or near the point of use of the materials and shall be used for long term storage of hazardous materials.

### B.2 Storage and Staging Areas:

Hazardous-substance storage areas shall be out of the normal flow of personnel traffic and shall be located near the loading dock for easy access to the trucks used to transport the waste for processing. See Section 4-2-10-D.1 Loading docks & Shipping and Receiving

Areas," and Sections 2-3-10-G.7 and 2-4-10-H.10 "Loading Dock Space Descriptions and Requirements." Convenient access from the storage room to the freight elevator shall be provided without having to traverse heavily used corridors so as to minimize the risks to the building occupants during the transport of the waste.

The storage and staging area shall be large enough to store the hazardous substances and provide room for loading and unloading the drums or containers. If multiple substances are stored, the design shall allow incompatible materials to remain segregated while in storage. Spill containment in each section of the storage room shall be designed to contain any spills of hazardous waste resulting from mishandling the waste materials. The A/E shall propose alternative means for spill containment within the storage room. Options include a spill-containment curb around the room, secondary containment bins, shelving designed to contain spills, or a combination thereof. Any curb used for containment spills shall be designed to allow convenient ingress/egress using a drum trolley. Each section of the storage area shall be designed to contain a spill of a minimum of 4 L of liquid. The configuration of the storage area shall be designed to facilitate spill cleanup. Interior surfaces of the storage area shall be cleanable, corrosion resistant, and non-reactive.

A chemical-resistant coating shall be applied to the walls and floor in this area to facilitate the cleanup of spills. These areas shall be thoroughly caulked and sealed to minimize pest harborage and exclude pests.

Safety equipment including emergency eyewash, emergency shower, and a telephone shall be provided for each storage room and staging area. The telephone to contact emergency response personnel shall be located either in the room or within 10 m of the room. Fire protection design requirements shall apply if flammable materials are stored.

## B.3 Hazardous Waste Storage and Handling at On-Campus Buildings:

Laboratory and animal research facility buildings on the NIH campus shall be designed with a room for temporary storage of hazardous waste and radioactive wastes. Mixed waste (hazardous waste that is also radioactive) shall be treated as radioactive waste in this temporary storage area. Hazardous waste is generally stored in this room for several hours or overnight. Refer to Section 1-9-10-F.3 "Radioactive Waste Storage."

Layout and Size: Two individual sections shall be designed: one for hazardous waste and one for radioactive waste. The storage room shall be large enough to provide for temporary storage of the hazardous waste and radioactive waste, and for storage of specialized carts to transport the hazardous waste from the laboratories. The hazardous waste storage section shall be 2.5 m x 3.5 m minimum. The radioactive waste storage section shall be 0.75 m x 1.5 m minimum.

Storage Cabinets: A minimum of three 2 m-high storage cabinets shall be provided in each room to provide segregated storage of incompatible materials. Open floor space in the storage room shall accommodate one 1 m-long waste cart and allow access to the storage cabinets and shelving.

Spill Containment: Waste materials are normally transported using specialized carts that provide spill containment. Spill containment shall be designed per Section 1-9-20-B.2.

Floors and Walls: Floor and walls shall be designed per Section 1-9-20-B.2.

Ventilation System: A separate ventilation system shall be installed for the storage room. Exhaust shall be directed away from the building and surrounding buildings' air intake. This ventilation system shall be connected to the building's emergency power system.

Lighting: Standard illumination requirements apply to this room.

Fire Protection: Sprinkler protection in the room shall be designed to meet the requirements for Ordinary Hazard Group 2.

Safety Equipment: Safety equipment shall be designed per Section 1-9-20-B.2.

Design Review and Approval: The DRS shall review all designs for hazardous waste storage rooms and shall provide the final approval of the design. The Project Officer shall coordinate this review and approval.

## B.4 Hazardous Substances Storage and Handling within Laboratories on the NIH Campus:

Laboratory Modules: All laboratory modules shall be designed for the safe storage of hazardous substances while discouraging the storage of excessive amounts of hazardous substances. All wet laboratories shall contain an approved ventilated acid (corrosive) cabinet and an approved flammable materials storage cabinet. The sizes of these cabinets shall be based on the volume of corrosive and flammable materials used in the laboratory. The location of radioactive storage cabinets shall be standardized in the laboratories to assist emergency response personnel, optimally located near the laboratory door for convenient access by the technician collecting the hazardous waste. For laboratory modules with a service corridor, the storage area shall be located near the service entrance rather than the hall entrance, avoiding the transport of hazardous waste through the main corridors of the laboratory building. There shall be no flammable storage cabinets located under fume hoods. Acid storage cabinets shall be ventilated and are typically located beneath fume

hoods. If no fume hood is present, exhaust ventilation must be provided to these cabinets. Acid cabinets and flammable material storage cabinets shall be located diametrically opposed from each other and towards the back of the laboratory away from the laboratory entrance.

Hazardous Waste Storage and Handling at Off-Campus Buildings: Laboratory buildings located in Montgomery County, Maryland, but not located on the NIH campus shall be designed per this section. Hazardous waste may be stored in these rooms from 60 to 90 days.

Location: The storage room shall be located near the loading dock for easy access to the trucks that will be used to transport the waste to the NIH campus for additional processing. Since this waste will be transported over public roads, the room shall also be used to prepare the hazardous waste for shipment. Processing conducted in this room includes bulking waste into larger containers, laboratory packing individual waste containers, and labeling and manifesting the containers for shipment.

Convenient access shall be provided from the storage room to the freight elevator without having to traverse heavily used corridors. Since these laboratories are typically leased space, it may be difficult to meet these criteria. In this case, consideration shall be given to alternate uses of this leased space that will not generate hazardous wastes.

Layout and Size: The storage room shall be divided into two sections. The first section shall be large enough to provide for temporary storage of the hazardous waste as it is received from the laboratories and after it has been packed for shipment. The second section shall be used for bulking and packaging the waste. Space for preparing manifests and other documentation shall be provided, either in the storage area or in an additional space outside the room. Space for storing specialized carts used to transport the hazardous waste from laboratories shall also be provided.

Spill Containment: Spill containment shall be designed per Section 1-9-20-B.2.

Floors and Walls: Floor and walls shall be designed per Section 1-9-20-B.2.

Ventilation System: The ventilation system shall be designed per Section 1-9-20-B.3 plus the following:

- The ventilation system shall be spark proof.
- The ventilation system shall be designed to allow easy access for routine or emergency maintenance from outside the containment area.

Safety Equipment: Safety equipment shall be designed per Section 1-9-20-B.2.

Fume Hood: A walk-in fume hood shall be provided in the bulking and packaging area, where exposure to harmful fumes is possible.

Explosion-Proof Design: An explosion panel designed to dissipate the impact of an explosion shall be provided in the storage room.

Lighting: Explosion-proof lighting shall be provided in both areas.

Fire Rating: Storage room walls shall have a two hour fire rating.

Design Review and Approval: DEP, DRS, and DOHS shall review all designs for hazardous waste storage rooms and shall provide final approval of the design. The Project Officer shall coordinate this review and approval.

## C. Hazardous Substances Storage and Handling within Laboratories Not on the NIH Campus

### C.1 Modules:

All laboratory modules shall be designed for the safe storage of hazardous waste generated by laboratory activities. The volume of hazardous waste generated by a laboratory is a function of the type of work being performed in the laboratory. The A/E shall consider the function of the laboratory to determine the space necessary for hazardous waste storage. At a minimum, a 0.75 by 0.75 m area shall be required.

The A/E must also recognize that some types of hazardous waste may be incompatible and shall design the hazardous waste storage area to accommodate multiple containers. The A/E shall investigate the possibility of stacked containers that will provide sufficient storage space while minimizing the footprint in the laboratory. However, hazardous containers shall not be stacked. Each storage container shall be designed to provide secondary containment of hazardous wastes. This storage area shall have a minimum of two physically separated sections to allow segregation of incompatible materials. Some laboratories may require three segments depending on the types of hazardous waste that will be generated. Storage areas shall be designed per Section 1-9-20-B.4

The location of the hazardous waste storage area in laboratories shall be standardized to assist emergency response personnel and shall be designed per Section 1-9-20-B.4

## C.2 Bulk Storage Facilities:

Above Ground Storage Tanks: The A/E shall consider the use of clean-burning fuels such as natural gas or liquid propane. Above ground storage tanks shall be provided in accordance with state of Maryland and Montgomery County, Maryland, requirements if fuel storage is required (i.e., a day tank ensuring uninterrupted availability of fuel).

All above ground storage tanks shall be double walled, be provided with secondary spill containment, and meet the requirements of the American Petroleum Institute and the NFPA. The tanks shall also be consistent with the NIH Spill Prevention, Control, and Countermeasures Plan.

Above ground storage tanks shall be located to provide access for delivery trucks. Concurrently, the tanks shall be sufficiently isolated and protected from traffic flow to minimize the risk of accident. The tanks shall be placed in a location to minimize the aesthetic impact of the tank on the surroundings, including the use of beams and landscaping to block the view of the tanks.

Spill Control: All bulk storage facilities and above-ground storage tanks shall be equipped with secondary containment to prevent discharge of the material in the event of a spill or a leak. For single storage tanks, the secondary containment shall be large enough to contain the volume of the tank and rainfall from a 10 year, 24 hour storm. For multiple storage tanks, the secondary containment shall be large enough to contain the volume of the largest tank and rainfall from a 10 year, 24 hour storm.

Materials used to provide the secondary containment shall be impervious to the substance contained in the storage tank. The containments shall be equipped with a normally closed valve to prevent accidental discharge of the substance from the containment. This valve can be manually opened to discharge accumulated rainwater after it has been determined that the water is not contaminated.

Other potential spill areas for hazardous substances on the campus are loading docks where spills can occur during the loading and unloading of hazardous substances or hazardous wastes.

Loading docks shall be designed to contain spills of hazardous substances and minimize the contamination of storm water runoff. The loading dock shall be provided with grate drains equipped with a normally closed valve to prevent accidental discharge of spilled substances, and to accumulate any spilled substances at the base. Uncontaminated runoff would be diverted from this drain by a second grate drain and a small berm. An overhang would divert direct rainfall from the base of the loading dock to the uncontaminated runoff

drain. The A/E may propose alternative designs that meet this objective. For control of storm water runoff and water quality, see Chapter Civil Engineering & Site Development "Storm Water Management" Section 3-1-10-C.

## C.3 Wastewater:

Wastewater Discharge: Only uncontaminated storm water runoff shall be discharged from the NIH campus to the receiving stream. All wastewaters generated on the NIH campus shall be discharged to the sanitary sewer. Wastewaters generated on the NIH campus include domestic sewage from the lavatory facilities, nonhazardous waste discharged from laboratory or research area sinks, waters used for cage washing and animal care, waters used in cafeteria operations, and all floor drains.

Wastewater Sampling: The NIH campus is connected to the WSSC sanitary sewer system. The NIH is permitted to discharge wastewater to the WSSC system through a Discharge Authorization Permit. Under the terms of this permit, the NIH must sample its wastewater four times every six months and submit an Industrial User Effluent Compliance Permit report to WSSC twice per year.

The wastewater sampling is conducted at two locations where NIH sewers connect to the WSSC system. However, for new laboratory and animal facility construction, the sanitary system shall be designed to allow for sampling at the discharge point from the individual building. This will allow for testing and troubleshooting of individual building wastewater streams.

The sampling point shall be designed to allow for installation of a continuous pH monitor, installation of a programmable sampler, and personnel access for grab sampling. Cage washing facilities and laboratory facilities shall be provided with a continuous pH monitor and recorder. The pH monitor shall provide an alert to the building automation system.

Wastewater Treatment: Since the NIH utilizes the WSSC system, it is normally not necessary to perform wastewater treatment on campus. However, it may be necessary to provide neutralization and equalization of wastewater streams from some laboratory and animal care buildings to comply with WSSC requirements and to minimize the risk of damage to NIH campus piping infrastructure.

Biomedical Laboratory Buildings: To allow for these circumstances, the waste systems for new buildings shall be arranged to allow for installation of an active-type pH neutralization system to serve laboratory and cage wash areas, and other potentially corrosive waste streams. The pH neutralization system shall be capable of neutralizing acid and caustic wastes without requiring installation of future pumping systems for any but the lowest levels

of the building that could not otherwise drain by gravity. The potential future arrangement provisions shall be planned and described in the Basis of Design document or on drawings. Sufficient planning shall be provided in the design arrangement to preclude the need for significant re-piping of the waste systems or other major disruptions in the event such systems become a future requirement.

Animal Research Facilities: In general, the sanitary system for new facilities that include animal care areas shall be equipped with an active pH treatment system or a continuous automatic pH monitoring system. Each pH monitor shall be arranged to permit maintenance and calibration without requiring disruption to building operations.

Tanks: Tanks used for equalization and neutralization of wastewaters can accumulate sludge and hazardous wastes, require maintenance, and cause odor problems. Therefore, equalization and neutralization tanks shall not automatically be installed in new construction. The A/E shall investigate the potential use of the building and attempt to characterize the potential wastewater stream on the basis of this proposed use. One of the following shall be provided for laboratory, clinical, vivaria facilities, depending on facility needs:

- An automatic pH monitor shall be installed on the laboratory waste line from each building. The pH monitor shall incorporate a normally closed lockable bypass to permit maintenance without requiring disruption of building operations. Buildings provided with automatic pH treatment systems for the main laboratory/vivarium effluent shall incorporate the pH monitor as part of the treatment system, and shall not require a separate monitor. The system shall include a chart recorder or preferably an electronic recorder to record pH excursions. The pH sensor shall be designed to preclude the trapping of solids.
- Laboratory and vivarium buildings shall incorporate an active pH treatment system, capable of automatically neutralizing both acidic and caustic waste streams. The system shall include a chart recorder or preferably electronic record to record pH excursions. The treatment system shall be designed to automatically handle normal solids and minimize accumulation of sludge. Passive systems consisting of tanks requiring use and refill of solid media (i.e. limestone or marble chips) shall not be utilized. The system shall include a lockable bypass or other means to allow for continued operations during maintenance; however, the bypass arrangement shall not bypass continuous pH monitoring capability.

Silver Recovery: Any facility designed with darkrooms or photo processing facilities shall have a processing facility for recovering silver from the wastewater stream from the photo processing rooms.

## D. Solid Waste

## D.1 Waste Minimization:

All biomedical laboratory and animal research facilities at the NIH shall adhere to the Environmental Protection Agency (EPA) solid waste management hierarchy, encouraging reduction of waste at the source. This hierarchy emphasizes waste minimization as the first step in sound solid waste management. The utilization of reusable products, which also has the effect of reducing the overall solid waste stream, is also encouraged. Waste products that cannot be reused shall be investigated to determine whether they can be recycled. Only those products that cannot be reused or recycled shall enter the waste stream for energy recovery or land filling. In general, solid waste management is an operational function. However, the requirements for environmentally friendly solid waste management shall be included in the design of new construction in order for the solid waste management system to be efficient and convenient to use. Ease and convenience are keys to implementation of a successful solid waste management program. All facilities shall be designed with modern and sanitary waste compaction equipment. This equipment shall minimize spillage of wastes and debris, and the attraction of pests.

Hazardous substance storage capacity can assist in laboratory waste minimization. The A/E shall closely examine the anticipated use of the laboratory to determine a reasonable volume of hazardous substances stored in the laboratory to allow efficient laboratory operations. Excessive storage space in a laboratory can result in over purchasing, hoarding of hazardous substances, and possible storage beyond useful shelf life, resulting in excessive hazardous waste generation.

## D.2 Recycling:

The NIH campus has an active solid waste recycling program. The program is administered by ORF. This program establishes white office paper, baled corrugated cartons, aluminum cans, and polypropylene as primary recycling materials. Mixed paper, wood pallets, scrap metal, polystyrene, food and beverage containers, and yard waste are designated as secondary recyclable materials.

All new construction on the NIH campus shall be designed to be recycling friendly. Collection containers placed at convenient locations throughout the building enable NIH employees to accumulate recyclable materials. The selection of recyclables to be collected; the type, size, and number of collection containers; and the locations for the collection containers shall be determined by the A/E on the basis of the planned use of the new facility. The A/E shall coordinate this selection with DEP.

Support facilities for recycling shall be included in all new construction. These support facilities include space in the loading dock area for storing recyclable materials. Paper products,

particularly white paper, must be kept clean and dry to maintain market value and be stored in a way so as not to attract pests or offer them harborage, requiring either a room for storage or an enclosed container. Other recyclable materials also require sufficient container space. Multi-compartment recycling roll off containers are commercially available and may be used for recyclable storage and transportation. The potential for attraction of pests, such as flies, wasps, or rodents, to these containers shall be considered when designing a placement site. The placement of these containers shall not affect personnel using the loading dock.

A can-flattener shall be considered for any facility expected to generate sufficient aluminum cans. The selection of the recycling support facilities and equipment required for all new construction shall be made by the A/E in coordination with DEP. Potential options for the loading dock design have been developed by the ORF and can be used per program requirements by the A/E.

## D.3 Hazardous Waste:

All hazardous waste generated on the NIH campus shall be handled in accordance with the NIH's generator and Treatment Storage and Disposal (TSD) permits. Generally, this requires accumulation of the waste at the generation point, temporary (one day or less) staging at the building loading dock, and transportation to Building 21 for processing. Any facility that cannot meet this format shall be considered a special exception to the DRM. The A/E shall develop the solid and hazardous waste design for this building in consultation with DOHS and DEP.

## E. Decommissioning:

NIH campus facilities shall be decommissioned prior to renovation. In this context, decommissioning is defined as all work required resulting in a facility free of chemical, biological, radiological, or other hazardous materials; and prepares the area for reasonable, unrestricted demolition. Decommissioning shall include an in-depth facility assessment by a qualified environmental engineer, approved by the DOHS and DEP.

The facility assessment shall identify any environmental or other site hazards that could result in the release of hazardous substances during demolition or could pose a hazard to workers.

Potential hazards addressed during the facility assessment include, but are not limited to, asbestos containing building materials (ACBM), polychlorinated biphenyls (PCB), lead and lead paint, mercury, underground storage tanks, hazardous substance storage areas, and spills of hazardous materials. Potential hazards are outlined in the "Checklists for Hazardous Substances" available from DEP. Because new and changed regulations have an im-

pact on the decommissioning process, Project Officers and A/E's must obtain the latest edition of this document from DEP for each project.

## E.1 Condition Assessments:

The condition assessment shall include the following quantitative data to substantiate the qualitative assessment:

- Review of records regarding the design, construction, and use of the building to be demolished and the site.
- Review of records regarding responses to hazardous substances spill incidents or other emergencies.
- Visual inspection of the building and site.
- Sampling and analysis of subject materials.

Condition assessments are required for every NIH renovation project, regardless of facility type. The end result of the condition assessment shall be a Decommissioning Plan for the facility, which shall include all recommended procedures for decontamination.

## E.2 Decommissioning Guidelines:

Decommissioning guidelines are under development by the DEP. Draft guidelines are outlined in the "Assessment and Decontamination of NIH Facilities for Alterations and Decommissioning" available from DEP. Until final guidelines are published by DEP, ORF guidelines requiring a site/facility assessment prior to demolition shall be required.

## E.3 Decommissioning Plan Review:

The DEP shall review and approve all decommissioning plans.

## E.4 Recycling Demolition Debris:

Prior to mobilization on the site, the demolition contractor shall be required to submit a waste disposal and recycling plan for the demolition activity to DEP. This plan shall identify each type of waste material generated by the demolition. The wastes shall be classified as hazardous waste, general waste, or recyclable waste. The alternatives for disposing or recycling of each type of waste material shall be discussed in the plan, with the objective of recycling the maximum amount of demolition materials. For any material not recycled, the contractor shall be required to document in the plan, to the satisfaction of the DEP, why recycling is not feasible.

# F. Radiation Safety:

Work performed at NIH laboratories involves the potential for occupational exposure to radioactive materials and other sources of ionizing and non-ionizing radiation. While laboratory procedures identify good radiation safety practices and techniques essential to minimize potential exposure to radiation, the security, containment, and shielding of this material and equipment through the use of good facility design are other extremely important elements.

The intent of this section is to provide A/E's with a working knowledge of the facility design parameters required for the construction of facilities, which shall provide for the control and containment of these radiation hazards. Not all sources of ionizing radiation are covered by NRC licensing. The non-licensed sources are, however, controlled by regulations issued by the DRS Officer upon recommendation by the radiation safety officer. Non-licensed sources include x-ray machines, high-voltage accelerators, electron microscopes, and radioactive materials from sources other than reactor by-products. In addition to the protection of occupationally exposed workers, DRS must ensure that the general public and surrounding environs are also provided with an adequate and similar degree of protection.

## F.1 Background:

DRS web site http://www.nih.gov/od/ors/ds/rsb/index.html provides guidance and technical information concerning the use of radioactive materials as well as policies and procedures for radiation-producing machines and areas. Radiation safety control, containment, and shielding design and laboratory practices have been developed to minimize the potential for radiation exposure to workers and radiation release to the environment.

## F.2 Specific Areas of Concern:

The following key radiation issues are identified relative to laboratory activities:

- Radiation safety requirements for laboratories using radionuclides.
- Radioactive airborne and liquid effluent sampling.
- Radiation safety requirements for devices used in medical research, such as x-ray machines, accelerators, and irradiators.
- Radiation safety requirements for non-ionizing radiation (only including MRI and high-intensity lasers (e.g., $CO^2$).
- Radioactive materials security requirements.

All radioactive materials stored at any NIH facility shall be secured. Unattended laboratories in which radionuclides are in use or stored shall be locked, or radioactive materials shall be locked in containers, refrigerators, or freezers. Other security options such as card key access shall be coordinated with DPSM.

## F.3 Radioactive Waste Storage:

Radioactive Waste Storage Buildings On Campus and Off Campus: All new biomedical laboratory and animal research facility buildings on campus and off campus shall be provided with a minimum of one radioactive waste storage room located inside and directly adjacent to the loading dock. The room shall provide a minimum of 14 m² of floor space. Only card key access shall be provided to the room. Other unique requirements for the radioactive waste room shall include:

Storage Requirements: Adjustable height bi-level metal shelving with lipped edges and corrosion resistant coating for spill containment to provide segregated storage of wastes of various compatibility classes shall be provided.

Flooring Specifications: A 100 mm (3'-0") high containment floor berm shall be provided at the entrance to the room for specified containment and be sloped to allow carts and dollies to easily pass. Two alternates are also acceptable:

- Room flooring designed 100 mm (3'-0"lower than corridor flooring with smooth transition ramp leading into room; or
- Room flooring designed to gradually slope away from the entrance to provide the same containment capacity.

No floor drains shall be located in this room. Flooring shall be of impervious material; highly resistant to organic solvents; non-slip; and with no cracks, joints, or drains. Floor and wall junctures shall be coved and of the same material as the floor.

Electrical Specifications: One duplex electrical outlet on each wall of the room shall be provided.

Medical Waste Cold Box: Medical waste cold boxes used to store MPW shall be used to store animal carcasses, tissues, and bedding contaminated with radioactive materials. Medical waste cold box storage room shall be located inside and directly adjacent to the loading dock. Contact DEP for medical waste cold box specifications.

Radioactive Waste Storage On-Campus Facilities: Laboratory buildings shall be designed with a separate area for the temporary staging of hazardous and radioactive waste. Mixed waste (hazardous waste that is also radioactive) shall be treated as radioactive waste in this temporary staging area described in previous sections of this chapter. Only specific issues that are directly related to radioactive waste are discussed here. Information on the carts and equipment for the transfer of radioactive waste currently in use can be obtained from DRS. The staging area shall be sized to provide for temporary storage of the radioactive waste and the specialized carts used to transport the radioactive waste from the laborato-

ries. The staging area shall be designed to contain any spills of radioactive waste that may occur during handling of the waste materials. This can be accomplished using specialized carts; however, the A/E may propose alternate means for spill containment. Special consideration shall be given to this area in the fire protection design per NRC Information Notice 90-09, specifying the fire protection and suppression systems to minimize the likelihood and extent of fire.

Coolers and/or walk-in freezers shall be located in each building with laboratories conducting biomedical research with radioactive materials.

Radioactive Waste Storage Off-Campus Facilities: Laboratory facilities not located on the NIH campus shall be designed with a room for use in processing and staging hazardous and radioactive waste. Mixed waste shall be treated as radioactive waste in this room. Only specific issues directly related to radioactive waste are discussed here. A 2 hour-rated wall shall be designed to separate radioactive waste and hazardous waste storage areas. The waste shall be transported to the NIH campus for additional processing and shipping to the long-term radioactive waste storage facility. Since the waste is transported over public roads, this room shall be used to prepare the radioactive waste for shipment. Processing conducted in this room shall include bulking of waste into large containers, laboratory packing of individual waste containers, and labeling and manifesting the containers for shipment. A bulking hood to perform these activities shall be provided. A service elevator on the premises shall be available to transport the radioactive waste to the appropriate marshalling area in the building. If a service elevator is not available, the use of a passenger elevator may be appropriate; however, dedicated times shall be required to transport the radioactive waste.

The staging room shall be divided into two separate sections. The first section shall be large enough to provide for temporary storage of the radioactive waste as it is received from the laboratories and after it is packed for shipment. The second section shall be used for bulking and packaging the waste. Sufficient space shall be provided for storing the specialized carts used to transport the radioactive waste from the laboratory. The staging room shall be designed to contain any spills of radioactive waste that may occur during handling of the waste materials. Spill containment in the bulking and packaging area may be accomplished with a curb around the area, secondary containment bins, or a combination thereof. These areas shall be thoroughly caulked and sealed to minimize pest harborage and exclude pests. It is important to note that prior to contracting for leased space that will require remodeling, renovation, or other extensive architectural or engineering work, DRS shall be informed and provide the necessary technical assistance.

Laboratory Module Requirements: All laboratory modules shall be designed for the safe storage of radioactive waste. The volume of radioactive waste generated by a laboratory is a function of the type of work being performed. The A/E shall consider the function of the laboratory to determine the space necessary for radioactive waste storage; recognize that some types of radioactive waste require segregation from other types; and design the radioactive waste storage area to accommodate multiple containers. All laboratories shall be designed to fit the appropriate low-level radioactive waste (LLRW) storage receptacles and/or containers. Contact DRS for specifications on these containers. Five LLRW streams have been identified from the NIH Waste Disposal Calendar, current edition:

1. Liquids - Aqueous waste and/or solvents/other hazardous chemical constituents (mixed waste)
2. Dry or solid waste (dry active waste) - Disposable lab ware and/or sharps (can also be categorized as MPW)
3. Liquid scintillation vials and/or bulk liquid scintillation media
4. Animal carcasses and/or tissues
5. Animal bedding and/or solid excreta

The size of the space dedicated to each of the containers shall be based on the volume of radioactive materials generated and/or research activities performed in the laboratory. Standard-sized containers are available from the radioactive waste contractor. Container placement locations shall be considered in the design. A standard location of the radioactive waste storage in laboratories shall be established to assist emergency response personnel. For laboratory modules with a service corridor, this storage shall be located near the service entrance rather than the hall entrance, eliminating the need for moving radioactive waste through the main corridors of the laboratory building. The configuration of the radioactive waste storage area in the laboratory shall be designed to facilitate radioactive material spill cleanup and decontamination. Interior surfaces of the storage area shall be readily cleanable for ease in decontamination. Corridors and public space shall not be designated and used for storage, and equipment such as refrigerators and freezers shall not be designated to store this material in these areas. The A/E shall include the following in the design:

- Physical security measures and mechanisms against unauthorized access in all laboratories.
- Security for all radioactive materials in laboratories when unattended.
- Space for shielding waste containers.
- Appropriately sized laboratory and marshalling areas for reduction of storage and/or waste accumulation.
- Appropriate spill containment for all storage areas.

- Potential shielding requirements between adjoining or adjacent laboratory bench areas for high-energy beta emitter radionuclides.
- Compensation for the additional weight required for lead shielding in the design of countertops and hoods if the laboratory is used for high-energy gamma emitter radionuclides.
- Secure equipment alcoves for storage of radioactive materials and/or irradiator equipment.
- Security provisions in construction specifications (e.g., locks as part of the integrated system, to secure this equipment) when storing radioactive materials in refrigerators and/or freezers.

## F.4 Module Requirements:

Beta barriers for shielding energetic beta emitters (P-32), often transparent plastic sheets, 0.95 cm to 1.27 cm thick, shall be provided to protect personnel in adjacent and close work areas.

## F.5 Ventilation Systems:

Ventilation systems used for controlling airborne radioactive discharges require the following:

- Laboratory exhausts shall be manifolded into the regular building exhaust.
- Hoods for bulking radioactive materials shall have sampling capability.
- Mechanical room space shall be designed to provide for future additional filtration capability.

If the facility requires additional hoods, specifically for the use of iodination techniques, then the exhaust from these installations shall be equipped with HEPA or charcoal filtration capability. A distinct installation shall be considered separate from the main exhaust system.

## F.6 Radioactive Airborne and Liquid Effluent Discharges:

DRS prohibits discharge of radioactive material into laboratory sinks. Provision shall be made in the design for installation of appropriate sampling probes for sampling capability to assess airborne and liquid effluent discharge streams, including main exhaust systems, sufficient to demonstrate compliance with the requirements of 10 CFR 20.1302. Liquid effluent monitoring can be accomplished by batch, composite, or continuous sampling prior to discharge into the sanitary sewer system. Design and construction considerations for airborne radioactive effluent monitoring shall include the following:

- All systems for use with radioactive materials shall have the capacity to sample the airborne effluent being discharged, primarily gases and vapors.

- Sufficient capacity shall be provided for sampling the combined discharge, specifically gases and vapors, at a common point located inside the mechanical room downstream of the filters and fans.
- Where iodination is performed in specific laboratories, those hoods shall be equipped to accept appropriate HEPA and charcoal filters.
- Airborne radioactive effluent monitoring systems shall be designed in accordance with ANSI Standard N13.1, Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities (1969), specifically Appendix A, Guides for Sampling from Ducts and Stacks.
- A single-nozzle sample probe shall be designed inside the air stream for sampling gas and vapors, as specified in ANSI Standard N13.1.

Laboratory design considerations shall include state-of-the-art design considerations, as specified by ANSI, and other acceptable industry standards, such as the following:

- National Council on Radiation Protection and Measurements (NCRP), Report No. 59, Operational Radiation Safety Program, Chapter 3, November 1, 1980.
- Hanson and Blatz, Radiation Hygiene Handbook, Section 9, Facility Design, 1959.
- Epoxy coatings, laminates, floor coverings, and protective coatings shall be utilized for ease of decontamination and to provide a protective coating that can be readily removed without extensive damage to the existing facility and surfaces.
- Sinks shall be either plastic composite or coated with epoxy or the equivalent to ease decontamination of surfaces. Stainless steel is also an option for sinks. Soapstone shall not be used.

Air filtration systems (activated charcoal/HEPA filtration) shall be installed and tested in accordance with ANSI/American Society of Mechanical Engineers Standard N510- 1980, Testing of Nuclear Air Cleaning Systems. The activated charcoal and HEPA filters shall be tested with current state-of-the-art methods and techniques for filter efficiency and compliance with technical specifications at the factory and after installation at NIH facilities. Chemical fume hoods for radionuclide use shall be designed in accordance with the following industry criteria and technical specifications:

- Landis and GYR Powers, Inc., Laboratory Control and Safety Solutions Application Guide, 1993.
- ACGIH, Industrial Ventilation: A Manual of Recommended Practice (current edition).
- Hoods shall have a minimum face velocity of 100 m/s.

A typical chemical fume hood designed for hazardous materials is acceptable as a radioisotope fume hood. The hood design shall include smooth, nonporous surfaces for ease of decontamination. The fume hood shall be constructed of materials that will not generate

mixed waste if the surfaces and the construction materials interact with the radioactive materials.

## F.7 Vacuum Systems:

Vacuum systems shall be protected with appropriate filtration (0.3 micron hydrophobic filter or the equivalent) to minimize the potential for contamination of vacuum pumps. Filters shall be on the suction side of the pumps, with exhaust to the outside of the facility and not recirculated into the mechanical spaces. Filters shall be located as close as possible to the laboratory in order to minimize the potential contamination of vacuum lines and to preclude and minimize decontamination and decommissioning costs. Filter housings shall be designed for easy filter replacement in order to minimize the possibility of maintenance worker contamination and to provide for easy disposal.

## F.8 Irradiators Utilized in Medical Research:

DRS shall be contacted when designing/installing an irradiator. Irradiators are designed to contain significant amounts of radioactive material and therefore are designed with engineering controls, as well as adequate shielding to perform the necessary functions utilized in medical research. The following facility design parameters shall be evaluated and satisfied for the construction to adequately house this equipment:

- Adequate structural integrity of floor loads given the amount of shielding, and associated weight, of this equipment.
- Adequate available means for moving this equipment to its location (e.g., loads on elevators and pathways).
- Feasibility and preference to locate equipment on the lower floors of a facility (e.g., ground floor, basement, or subbasement) due to shielding requirements.
- Security or the capability to be secured (locked) for the room and/or facility housing the irradiator.

## F.9 Radiation-Producing Equipment and/or Machines:

DRS shall be notified when there is any change in the setup of radiation-producing equipment or machines. This includes purchase and installation of new equipment, changes in shielding, changes in the output of the radiation, or changes in usage of the unit. With respect to the use of radiation producing equipment and/or machines, the following design guidance shall be used:

- National Council on Radiation Protection and Measurements (NCRP), Report No. 102, Medical X-Ray, Electron Beam and Gamma-Ray Protection for Energies up to 50 Mev (Equipment Design, Performance and Use, 1989).

- NCRP, Report No. 49, Structural Shielding Design and Evaluation for Medical Use of X-Rays and Gamma Rays of Energies up to 10 MeV, September 15, 1976.
- NCRP, Report No. 17, Structural Shielding Design for Medical X-Ray Imaging, November 19, 2004.

The documents referenced above shall be used by DRS to:

- Implement an "as low as reasonably achievable" (ALARA) program to minimize radiation exposure to occupationally exposed individuals and the general public.
- Provide the appropriate design criteria as they relate to radiation-producing equipment and/or machines.
- Provide structural shielding requirements for any new installations or installations undergoing renovations or changes.

The following factors, such as W (workload), U (use factor), and T (occupancy factor), as defined in the appropriate NCRP handbooks, shall be utilized to calculate and design the necessary shielding requirements. The dose equivalent limit for design purposes shall be 10-mRem public exposure and 500-mRem occupational exposure.

## F.10 Non-Ionizing Radiation:

This section applies only to MRI and high-power intensity lasers. With respect to the use of MRI devices, the following regulations and design considerations apply:

- U.S. Food and Drug Administration (FDA) regulations 21 CFR 892.1000, Magnetic Resonance Imaging.
- Security requirements for housing and enclosing the equipment.
- Warning placards, signs, and postings, which may also include barriers.
- Warning requirements for cardiac pacemakers as well as other prosthetic devices and/or equipment.
- Shielding requirements to minimize radiation exposure to electric and magnetic fields.
- Posting concerning electrical hazards.

With respect to the use of lasers, specifically high-power intensity lasers, the following regulations and design considerations apply:

- FDA regulations 21 CFR 1040, Performance Standards for Light-Emitting Products.
- ANSI Standard for the Use of Lasers, ANSI Standard 2136.1, 1986.
- Conference of Radiation Control Program Directors, Frankfort, Kentucky. Suggested State Regulations for Control of Radiation, Volume II: Non-Ionizing Radiation (latest edition).

- Security requirements for housing and enclosing the equipment.
- Warning placards, signs, and postings, which may also include barriers.
- Appropriate personal protective equipment warnings prior to entering and/or working with the equipment to mitigate and prevent eye and skin exposure.

A Class III laser system is a medium-pulse system requiring control measures to prevent viewing of the direct beam. Design and control measures emphasize preventing direct access to the primary or reflected beam. Safety eyewear is necessary and required with this class of laser. High-power intensity lasers (e.g., $CO_2$ lasers) are classified as Class IV lasers in 21 CFR 1040. These lasers produce radiation so powerful as to cause injury with a direct or reflected exposure, even when the beam is scattered or diffused by a rough surface or smoke screens. Class IV radiation lasers emit more than 0.5 W continuous output. Laser facilities shall be designed to minimize the use of reflective/refractive surfaces to provide additional protection to occupational personnel.

# Section 1-10: Sustainable Design



## 1-10-00 Policy

As defined in the HHS Sustainable Buildings Implementation Plan, all construction projects will incorporate the *Guiding Principles* of the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (MOU) into the planning, design, construction, operation, maintenance, and decommissioning processes. Construction projects under the scope of this policy, which have a total project cost equal to or greater than $3 million, will obtain certification from the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED™) or the Green Building Initiative's Green Globes™ System.

Existing facilities will incorporate the *Guiding Principles* of the MOU to the maximum extent feasible in all improvement, repair and maintenance projects. In addition to incorporating the *Guiding Principles* of the MOU, improvements and repair projects, which have a total project cost equal to or greater than $10 million and/or impacting 40% or more of the overall floor area, will obtain certification from the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED™) or the Green Building Initiative's Green Globes™ System.

In addition, existing buildings shall be assessed for compliance with the *Guiding Principles* of the MOU to ensure that 15% or more of the HHS capital asset building inventory incorporates the sustainable practices in the *Guiding Principles* by FY 2015. The HHS capital asset building threshold for incorporating sustainable practices in existing buildings is 5,000 gross square feet or more, excluding housing. New housing projects with a total project value greater than $3 million shall be designed to obtain LEED™ certification from the U.S. Green Building Council (USGBC). New housing projects with an estimated construction cost of less than $10 million may alternatively obtain a third-party Green Globes ™ certification from the Green Building Initiative (GBI). Projects in existing housing that are greater than $3 million in total project cost and impact more than 60% of any individual unit shall also obtain third-party certification.

All new lease actions 5,000 useable square feet (usf) or more will incorporate the *Guiding Principles* of the MOU to the maximum extent feasible. New lease actions under 5,000 usf will consider the *Guiding Principles* as one criterion for lease evaluation. A build to suit lease will be a LEED™ certified building.

Requests for waivers shall be considered on a case-by-case basis for individual projects. The Deputy Assistant Secretary, Office for Facilities Management and Policy, Office of the Assistant Secretary for Administration and Management (OFMP/ASAM) must approve waivers and any other exceptions to the provisions of this policy as required by E.O. 13423.

To the maximum extent feasible sustainable design practices shall be considered in the design requirements for facilities funded through extramural construction grants of $1 million or more.

## A. HHS Guiding Principles for New Construction, Major Renovations and Leases

### A.1 Employ Integrated Design Principles

Integrated Design: Use a collaborative, integrated planning and design process that: Initiates and maintains an integrated project team in all stages of a project's planning and delivery. Establishes performance goals for siting, energy, water, materials, and indoor environmental quality along with other comprehensive design goals; and, ensures incorporation of these goals throughout the design and lifecycle of the building; and, considers all stages of the building's lifecycle, including deconstruction.

Commissioning: Employ total building commissioning practices tailored to the size and complexity of the building and its system components in order to verify performance of building components and systems and help ensure that design requirements are met. This should include a designated commissioning authority, inclusion of commissioning requirements in construction documents, a commissioning plan, verification of the installation and performance of systems to be commissioned, and a commissioning report.

### A.2 Optimize Energy Performance

Energy Efficiency: Establish a whole building performance target that takes into account the intended use, occupancy, operations, plug loads, other energy demands, and design to earn the ENERGY STAR® targets for new construction and major renovation where applicable. For new construction, reduce the energy use by 30 percent compared to the baseline building performance rating per the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., (ASHRAE) and the Illuminating Engineering Society of North

America (IESNA) Standard 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential. For major renovations, reduce the energy use by 20 percent below pre-renovations 2003 baseline. Laboratory spaces may use the Labs21 Laboratory Modeling Guidelines. If available, use Energy Star and FEMP-designated Energy Efficient Products.
Per the Energy Independence and Security Act (EISA) Section 523, meet at least 30% of the hot water demand through the installation of solar hot water heaters, when life cycle cost effective.

Per Executive Order 13423, implement renewable energy generation projects on agency property for agency use, when life cycle cost effective.

Measurement and Verification: Per the Energy Policy Act of 2005 (EPAct) Section 103, install building level utility meters in new major construction and renovation projects to track and continuously optimize performance. Per EISA Section 434, include meters for natural gas and steam, where appropriate.

Compare actual performance data from the first year of operation with the energy design target. After one year of occupancy, measure all new major installations using the ENERGY STAR® Portfolio Manager for building and space types covered by ENERGY STAR®. For other building and space types, use an equivalent benchmarking tool such as the Labs21 benchmarking tool for laboratory buildings. Compare actual performance of Laboratory buildings through the Labs21 benchmarking tool.

## A.3 Protect and Conserve Water

Indoor Water: Employ strategies that in aggregate use a minimum of 20 percent less potable water than the indoor water use baseline calculated for the building, after meeting the EPAct 1992, Uniform Plumbing Codes 2006, and the International Plumbing Codes 2006 fixture performance requirements. The installation of water meters is encouraged to allow for the management of water use during occupancy.

Outdoor Water: Use water efficient landscape and irrigation strategies, including water reuse and recycling, to reduce outdoor potable water consumption by a minimum of 50 percent over that consumed by conventional means (plant species and plant densities). The installation of water meters for locations with significant outdoor water use is encouraged.
Employ design and construction strategies that reduce storm water runoff and polluted site water runoff. Per EISA Section 438, to the maximum extent feasible, maintain or restore the predevelopment hydrology of the site with regard to temperature, rate, volume, and duration of flow using site planning, design, construction, and maintenance strategies.

Process Water: Per the Energy Policy Act of 2005 Section 109,when potable water is used to improve a building's energy efficiency, deploy life-cycle cost effective water conservation measures.

Water-Efficient Products: Use EPA's WaterSense Program-labeled products or other water conserving products. Choose irrigations contractors who are certified through a Water-Sense labeled program.

## A.4 Enhance Indoor Environmental Quality

Ventilation and Thermal Comfort: Meet ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, including continuous humidity control within established ranges per climate zone, and ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality.

Moisture Control: Establish and implement a moisture control strategy for controlling moisture flows and condensation to prevent building damage and mold contamination.

Daylighting: Achieve a minimum of daylight factor of 2 percent (excluding all direct sunlight penetration) in 75 percent of all space occupied for critical visual tasks. Provide automatic dimming controls or accessible manual lighting controls, and appropriate glare control.

Low-Emitting Materials: Specify materials and products with low pollutant emissions, including adhesives, sealants, paints, carpet systems, and furnishings.

Protect Indoor Air Quality during Construction: Follow the recommended approach of the Sheet Metal and Air Conditioning Contractor's National Association Indoor Air Quality Guidelines for Occupied Buildings under Construction, 1995. After construction and prior to occupancy, conduct a minimum 72-hour flush-out with maximum outdoor air consistent with achieving relative humidity no greater than 60 percent. After occupancy, continue flush-out as necessary to minimize exposure to contaminants from new building materials. Prohibit smoking within the building and within 25 feet of all building main entrances and building ventilation intakes during building occupancy.

## A.5 Reduce Environmental Impact of Materials

Recycled Content: For EPA-designated products, use products meeting or exceeding EPA's recycled content recommendations. For other products, use materials with recycled content such that the sum of postconsumer recycled content plus one-half of the pre-consumer content constitutes at least 10% (based on cost) of the total value of the materials in the project. If EPA-designated products meet performance requirements and are available at a reason-

able cost, a preference for purchasing them should be included in all solicitations relevant to construction, operation, maintenance of or use in the building.

Biobased Content: For USDA-designated products, use products meeting or exceeding USDA's biobased content recommendations. For other products, use biobased products made from rapidly renewable resources and certified sustainable wood products. If these designated products meet performance requirements and are available at a reasonable cost, a preference for purchasing them should be included in all solicitations relevant to construction, operation, maintenance of or use in the building.

Environmentally Preferable Products: Use products, such as low-emitting materials or products containing no toxic metals, that have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose.

Construction Waste and Materials Management: During a project's planning stage, identify local recycling and salvage operations that could process site-related construction and demolition materials. Include in the design the recycle or salvage of at least 50 percent of the non-hazardous construction, demolition and land clearing materials, excluding soil, where markets or onsite recycling opportunities exist. Provide salvage, reuse and recycling services for waste generated from major renovations, where markets or onsite recycling opportunities exist.

Ozone Depleting Compounds: Eliminate the use of ozone depleting compounds during and after construction where alternative environmentally preferable products are available, consistent with either the Montreal Protocol and Title VI of the Clean Air Act Amendments of 1990, or equivalent overall air quality benefits that take into account life cycle impacts.

## 1-10-10 Procedures

To promote the health of the public and our employees and minimize potential impacts of our mission activities on the environment, each Operating Division (OPDIV) of the Department of Health and Human Services (HHS) will incorporate sustainable and high-performance design principles in the planning, acquiring, siting, designing, building, operating, maintaining and decommissioning of all facilities.

Several policies and laws affecting facilities have been issued that promote and mandate the greening of the Federal Government. The design therefore shall provide for the protec-

tion of the environment through energy efficiency, recycling, pollution prevention, and affirmative procurement.

1. In January 2006, HHS joined 18 other federal agencies and authorities in signing the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (MOU) at the White House Summit on Federal Sustainable Buildings.

2. The Executive Order 13327 – Federal Real Property Asset Management and the HHS Real Property Asset Management Plan call for the Department to establish a sustainability policy.

3. In September 2006, the Department issued its initial policy for Sustainable and High Performance Buildings. In December 2006, the Department issued its initial Sustainable Buildings Implementation Plan (SBIP) for implementing the policy. The SBIP is updated every year with the latest information and policy.

4. In January 2007, Executive Order 13423 – Strengthening Federal Environmental, Energy, and Transportation Management replaced E.O. 13123, *Greening Through Efficient Energy Management*. The new E.O strengthens the energy efficiency requirements for federal facilities enforces and requires Agencies to incorporate sustainable practices consistent with the MOU Guiding Principles.

5. In December 2007, the Energy Independence Policy Act of 2007 was signed into law that is designed to increase energy efficiency and the availability of renewable energy and makes many of the sustainable practices and requirements law.

## 1-10-20 Guidance and Information

The policy for Sustainable and High Performance Buildings applies to all buildings under the control of the Department and all OPDIVs, including all buildings that are reported in the HHS Automated Real Property Inventory System (ARIS), whether owned or leased and operated by HHS, or operated on behalf of HHS. This policy does not apply to tribally owned and operated buildings under the authorities of P.L. 93-638.

The HHS Sustainable Building Implementation Plan (SBIP) is updated annually and addendums are included on a semi-annual basis when new policy or requirements are identified. Due to the continued improvement of sustainable technology and techniques, the use of the SBIP is encouraged to be aware of the latest information and reporting procedures concerning federal facilities requirements. References relating to sustainable design found in the

DRM are listed in Exhibit X1-10-A. The NIH Division of Environmental Protection will provide additional guidance.

Sustainable Design References

- Department of Health and Human Services. HHS Policy for Sustainable and High Performance Buildings. December 2007. Available: http://www.hhs.gov/asam/ofmp/hiperfbldngpol.pdf
- Department of Health and Human Services. HHS Real Property Asset Management Plan. Available: http://www.hhs.gov/asam/ofmp/ramp.doc
- Executive Order 13101: Greening the Government through Waste Prevention, Recycling, and Federal Acquisition. Available: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1998_register&docid=fr16se98-113.pdf
- Executive Order 13123: Greening the Government through Efficient Energy Management. Available: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1999_register&docid=fr08jn99-171.pdf
- Executive Order 13134: Developing and Promoting Biobased Products and Bioenergy. Available: http://www.archives.gov/federal-register/executive-orders/1999.html#13134
- Executive Order 13148: Greening the Government through Leadership in Environmental Management. Available: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2000_register&docid=fr26ap00-129.pdf
- OMB Circular A-11, Section 55-Energy and Transportation Efficiency Management. Available: http://www.whitehouse.gov/omb/circulars/a11/current_year/s300.pdf#search=%22OMB%20Circular%20A-11%20Part%207%22
- OMB Circular A-11, Part 7 (Section 300), Planning, Budgeting, Acquisition, and Management of Capital Assets Available: http://www.whitehouse.gov/omb/circulars/a11/current_year/s300.pdf#search=%22OMB%20Circular%20A-11%20Part%207%22
- The Federal Leadership in High Performance and Sustainable Buildings, Memorandum of Understanding. Available: http://www.energystar.gov/ia/business/Guiding_Principles.pdf
- Green Building Initiative Green Globes System. Available: http://www.thegbi.com/greenglobes/
- US Green Building Council. Available: www.usgbc.org
- Whole Building Design Guide Available: www.wbdg.org

# Section 1-11: Integrated Pest Management



## 1-11-00 Policy

Pest control is important because insect and rodent pests:

- Carry disease organisms on or in their bodies.
- Cause physical damage to building facilities (by chewing/gnawing).
- Contaminate and compromise the research environment.
- Are unacceptable in the workplace.

In order to provide safe, effective pest control that is compatible with the biomedical research environment, the DOHS Community Health Branch (CHB) has implemented Integrated Pest Management (IPM) programs in all NIH design and construction projects and throughout NIH workplaces. Professional entomologists on the staff of DOHS manage these programs.

Traditionally, pest control consisted of the general application of one or more pesticides. However, there has been a movement away from relying solely on pesticides to solve pest problems in response to public concerns over pesticide use, pesticide resistance, and the possibility that pesticide applications may contaminate the work environment and expose staff to pesticide residues.

The reliance on pesticides as the sole means to correct pest problems is unacceptable in the NIH biomedical research environment. NIH has implemented effective, long term prevention methods and strategies that work in unison with the building design and its use. Prevention of pest infestation in and around NIH buildings contributes to creating a better work and research environment.

Pests are dependent upon biotic factors to provide nourishment and moisture and abiotic factors to provide harborage and ingress into buildings. Through proactive steps taken during building planning, design, construction, and commissioning, resources for pests are minimized, thus diminishing pest infestation during the building's functional life cycle.

# 1-11-00 Guidance and Information

## A. Integrated Pest Management:

IPM is a safe and effective way to control pests. IPM is proactive in preventing pest problems, not reactive to an infestation, especially in animal research facilities. IPM discourages unnecessary pesticide use and generic prescriptive pesticide treatments. Each IPM program is specifically designed to meet the individual needs of the area serviced and is a continuing program in order to manage the environment where pests live and to meet future pest management needs.

The IPM program focuses on designing new projects that do not create conditions that encourage pests, and that minimize pesticide applications by reducing the amount of food, water, and harborage to pests.

## A.1 IPM Program Components:

Improvements in facility design and construction can significantly assist with maintaining good sanitation, housekeeping, and pest prevention. The basic components of an IPM program instituted during the design and construction phases significantly minimizing pest infestation of buildings during construction are:

- Facility Design: Proactive approach to facility designs not contributing to the harborage of pests.
- Structural Repairs: Performance of small repairs that exclude pests.
- Sanitation: Proper sanitation on the construction site; reduction of clutter and pest harborage; and banning cellulose type fill and/or debris.

Operational elements implemented during construction and facility occupation, include:

- Monitoring: Regular surveillance of an area using traps, visual inspections, interviews with staff, and surveys to determine if a pest problem exists; the location and size of the pest infestation; and conditions contributing to pest problems.
- Communication: Staff cooperation in correcting conditions that contribute to pest problems.
- Record-Keeping: Data monitoring of pest numbers and observations on housekeeping and structural deficiencies.
- Pest Control without Pesticides: Pest exclusion, trapping, screening, and caulking used as effective, long-term methods of pest prevention and applied with a high degree of safety and effectiveness.

- Pest Control with Pesticides: Pesticide application using the safest, most effective methods, and only where needed.
- Program Evaluation: Data/observations monitoring periodically summarized and reviewed to evaluate program effectiveness.
- Safety: Significant reduction of the use of pesticides through IPM; and emphasis on the use of more permanent nonpesticidal control practices, minimizing the potential of exposure to pesticides by the research environment and NIH staff.
- Quality Assurance: Technical oversight providing an objective, ongoing evaluation of program activities and effectiveness.
- DOHS CHB Involvement: CHB management of IPM programs in biomedical laboratories and animal research facilities, with involvement during the planning, design, and construction phases of new construction and alteration projects. The Project Officer and design team shall involve the CHB early during the planning and design process for any project to obtain input on proposed designs from the pest management perspective.

## B. Facility Design Elements

Buildings shall be designed and constructed to promote cleaning. This entails employing designs and materials that minimize gaps, voids, and inaccessible spaces. Construction materials shall be durable and chosen for the proper application to maintain building integrity to avoid gaps, holes, and voids where debris can accumulate and pests can harbor. General components of facility design and construction that impact an effective pest prevention program are:

- Overall facility design and construction, including the materials and construction detailing and the equipment and construction processes used to build the facility. Facility components and layout shall minimize points of pest ingress and harborage and optimize accessibility for cleaning, sanitation, and pest inspection.
- Housekeeping as it relates to design and sanitation, throughout the surrounding building area and inside the facility.
- Pest management service implemented during construction.
- Facility durability and sustainability. Over the life cycle of a facility, changes in the envelope, interior layout and equipment, and animal facility use and programs have a direct influence on pest activity in and around a facility.

Specific design requirements for facility design elements include:

- Building integrity. Closing cracks, crevices, and voids; penetrations through floors, walls, and ceilings; surface protection; and treatment and finishes affect pest activity. See Architectural Sections 4-2-10-B.6 and 4-7-00-C “Joint Sealants and Caulking” and Environmental Management/Radiation Safety Section 1-9-20-B.2 “Storage and Staging Areas”

- Staff support areas, including break rooms, locker rooms, and administrative and conference space. See “Section 2-3-20-G.5: Administrative, Interaction and Ancillary Space and Section 2-4-20-G.10 Offices and Miscellaneous Space” in animal research facilities.
- Shipping/receiving areas, including loading dock and storage facilities. See Sections 2-3-20-G.7; 2-4-20-H-10 and 4-2-20-D “Loading Docks”.
- Personnel entry points. See Chapter 2 Design Considerations.
- Solid waste management and removal; and recycling activities. See Environmental Management /Radiation Safety Section 1-9-20-D “Solid Waste.”
- Lighting on the site and building exterior. See Civil Engineering & Site Development; Section 3-4-20-A “Landscape Lighting Design Considerations”.
- Landscape design and management. See Civil Engineering & Site Development; Section 3-4-20-B “Other Landscape/Pest Management Considerations”.

## D. Pest Management Consultation, Design Review, and Program Support

The Project Officer and the A/E shall contact the Community Health Branch (CHB), during early planning stages of any design project to ensure that the design addresses all areas relative to pest management, including:

- Design Concept: Structural/design components (ranging from exterior design elements such as ledges to open or hollow voids in interior case work) that pose a potential or known pest problem shall be considered as early as possible in the design phase.
- Facility Fit-Out: Materials and equipment considered undesirable or unacceptable by IPM shall not be used.
- Onsite Consultation: Technical support by CHB staff provided during site visits and inspection during all phases of planning, design, construction, and renovation.
- Pest Management Services Oversight: All projects specifications shall include requirements for maintaining pest surveillance and control programs during all phases of construction. DOHS shall review and approve all IPM services plans and inspect all pest management services delivered by construction contractor personnel to ensure efficacy and IPM program quality.

## E. Pest Management Services during Construction

IPM services for the control of pests are required on all NIH construction sites during all phases of construction.

# Section 1-12: Special Requirements & Procedures



## 1-12-00 Policy

### A. CAD Drawings

All drawings shall be drawn and created using the latest version of Autodesk products including Architectural Desktop and associated Autodesk Building Systems software; and shall be drawn in 3D and 4D to create building information models of the project including A/E work. The drawings submissions shall be accessible for view by all reviewers using a centralized electronic drawing management system.

### B. Specifications

All construction contract specifications shall be created and edited using the latest version of the AIA MASTERSPEC®, except that NIH specific specification sections shall be used where available. New NIH sections will be released and old NIH sections will be archived continuously. The A/E shall check with the Project Officer for availability of specification sections at the start of each project. Throughout all specification divisions, all references to "Quality Assurance" shall be changed to "Quality Control."

AIA MASTERSPEC® is published by Architectural Computer Services (ARCOM) under a licensing agreement with the AIA available exclusively from ARCOM at (800) 424-5080.

AIA MASTERSPEC® is required as the base document for specifications for the purpose of making NIH specifications consistent, and not to require designs to conform to MASTERSPEC®. The A/E shall edit all specification sections to make the project conform to the DRM. MASTERSPEC® shall be used for everything that is adequately addressed in MASTERSPEC® sections. The A/E shall write new specification section or use another standardized specification system for a section or item that MASTERSPEC® does not cover.

## C. Security

The consideration of security components and incorporation of required elements early in the planning and design process is more economical than the incorporation of security elements during construction. Due to the unique security requirements of each project, the A/E shall contact NIH DPSM, through the Project Officer, in the early planning stages to ensure compliance.

### C.1 Applicability:

The NIH Physical Security Design Requirements (PSDR) contains specific security requirements, including critical security systems, and shall apply to all facilities to which the DRM is applicable.

### C.2 General

Policy: Nondisclosure Warning: The PSDR contains law enforcement-sensitive physical security design and construction criteria and standards for NIH buildings and facilities. Disclosure of these data to other than Federal officials or contractors without a specific need to know may compromise security of the facility and its occupants. Portions of the document, and the criteria, references, codes, and standards contained therein will be made available ONLY to those federal officials and contractors, contract employees, and identified consultants who have a direct need for the information to design a specified project. Precautions shall be taken to safeguard and control distribution of any portion of the PSDR, and any individuals provided copies shall assume responsibility for ensuring that the information is kept secure. See NIH Division One Specification Section 01350 for an outline of procedural requirements.

The PSDR is exempt from mandatory public disclosure under provisions of the Freedom of Information Act (FOIA), paragraph 5 USC 552(b) (2). Information contained in the document and the included tables shall be protected from potential adversaries. Users may classify the tables following Classified National Security Information contained in Executive 0rder 12958 and its Implementing Directives.

Contact DPSM through the Project Officer for all security information and Division of Personnel Security and Access Control (DPSAC) for personnel and background checks.

### C.3 Design Considerations for Select Agent Laboratories:

The A/E shall contact the Select Agent Program Manager (SAPM) if a select agent is to be used in the laboratory. The A/E shall also contact DPSM if the biosafety level is greater that BSL2/ABSL2. General principles of Select Agent Program (SAP) laboratory design in the planning stage shall include:

- Input of the user and NIH SAP, Responsible Official/Alternate Responsible Official in tandem.
- Determination of the Select Agent needs for the principal investigator (PI) i.e., long term storage, growing of materials, animal usage, etc.
- Determination of the biosafety level the PI envisions requiring and review of these determinations with DOHS.

General principles of SAP laboratory design in the design stage shall include:

- The ability to physically segregate personnel and equipment into separate workstations dependent upon the different organisms to be handled by the PI(s).
- Participation of Security and Emergency Response (SER), DPSM, ORS in the discussions as early on as possible.
    - Category A agents require cameras for long term storage and a dual method of security access control.
- CDC/NIH BMBL facility requirements compliance for the specific BSL.

Additionally all select agent laboratories' designs shall include:

- Compliance with the BMBL. Any "recommendation" for facility design made in the CDC/NIH BMBL is a regulation for each select agent laboratory (42 CFR 73).
- Compliance with the DHHS/SAP 12 point plan.
- Review by DPSM knowing that a select agent shall be used.
- Specification requirements for documentation (mechanical and plumbing reports) needed to register a laboratory with the CDC.
- Controlled access.
- Use of tamper resistant high security cylinders for keyed doors on the facility master lock only.

Any value engineering discussions, design modifications, renovations or questionable item shall be reviewed by both DOHS and the PI prior to final approval.

## D. Accessible Design (ADA-ABA Compliance):

All work covered by the DRM shall be in conformance with the Architectural Barriers Act (ABA), except where the NIH lease requires the Americans with Disabilities Act (ADA) compliance at http://www.access-board.gov/gs.htm. For additional information and updates go to http://www.access-board.gov/ada-aba/standards-update.htm. NIH cannot grant waivers and variance for ADA compliance. All requests must be submitted to the U.S. Access Board.

### E. Required Use of Registered or Licensed Design Professionals:

All designed work shall be overseen by a professional engineer or architect licensed in the state where the work is to be performed. All final design drawings and calculations shall be stamped and signed by a professional engineer or architect licensed in the state where the work is to be performed.

### F. Zoning and Integrity of Buildings:

The A/E shall design within the established zones in existing buildings, or modify the existing, or create new zones following patterns that are logical and considered reasonable industry practice. This requirement applies to functional and utility zones. It includes but is not limited to: power, lighting, HVAC; domestic, laboratory purified, heating, cooling, sprinkler, and other water systems; fire, security and equipment alarms; telephone, data, Building Automation Systems (BAS) and other networks, compressed air, vacuum, natural gas and other lab gas systems, and fire barrier systems. Some NIH buildings have written integrity guidelines that shall be followed. Where written guidelines are not available, the A/E shall research archive documents, perform field surveys, and test existing systems, so as to establish the intent of the original design and prepare design modifications to be within the intent of the original design, while meeting program requirements.

## 1-12-20 Guidance and Information

### A. Lines of Responsibility:

The “IC-Owned Equipment - Assignment of Responsibility for Construction, Maintenance, Monitoring, and Operations Service” covers areas where ORF and IC responsibilities may overlap. Items that are clearly part of the mission of ORF or the IC or other NIH offices do not affect the A/E’s responsibilities for designing basic heating, cooling, ventilation, lighting, normal power, emergency power, plumbing, compressed air, vacuum, gas, security, chemical, biological and radioactive waste handling, fire protection, phone, data, mail, building automation systems, etc., as described in the A/E’s scope of work. The A/E shall coordinate system requirements within the SOW to provide a complete set of construction documents, regardless of government funding venues.

# Section 1-13: Acceptance, Activation and Occupancy



## 1-13-00 Policy

### A. Purpose

The purpose of this section is to provide guidance that will facilitate transitioning from the construction phase of a project to beneficial use and operations by the user. Topic areas of particular significance to effective facility activation include inspection and acceptance, warranties, training, documentation in operations and maintenance manuals, and occupancy.

1. NIH activities may take beneficial occupancy or use after substantial completion of a facilities project is achieved. Potential risks, impacts and effects shall be care-fully considered when deciding whether to occupy or utilize a portion of a construction project prior to substantial completion of the whole project.
2. NIH activities shall ensure that an effective warranty management program is in place to enforce active material, equipment, and workmanship warranties for the benefit of the government.

### B. Definitions

For the purpose of Section 1-13 of this manual, the following definitions shall apply:

Latent Defect - Latent defect is defined in the FAR Subpart 2.1, as “a defect that exists at the time of acceptance but cannot be discovered by a reasonable inspection”.

Beneficial Occupancy - Beneficial occupancy takes place on the date when part or all of the work involved in a construction project is substantially complete and the Government takes possession of the designated space or spaces to use for the purpose intended. Beneficial occupancy also initiates the warranty period and the environmental mitigation identified in the environmental documents. (The use of a project or portion thereof for the purpose intended.)

Substantial Completion - The time when the contract work is complete to the point that the Government may take over the facility and receive beneficial occupancy for the purpose intended.

### C. Material Safety Data Sheets (MSDS)

MSDS shall be required from the contractor in a separate binder. A MSDS is designed to provide both workers and emergency personnel with procedures for handling or working with a particular substance. MSDS's include information such as physical data (melting point, boiling point, flash point etc.) toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill/leak procedures. These are of particular use if a spill or other accident occurs.

## 1-13-10 Procedures

### A. Laboratory Certification:

Laboratory certification is the systematic review of all safety features and processes associated with the laboratory to validate that all facility controls and prudent practices are in place to minimize, to the greatest extent possible, the risks associated with laboratory operations and the use of biohazard material. DOHS certification requirements for containment (BSL3) laboratories are outlined in the "National Institutes of Health Biosafety Laboratory Certification Requirements" (17 October 2006). The A/E shall obtain from NIH the "BSL3 Certification Guidelines," comprised of BSL3 Equivalency Process for BSL3 Certification, BSL3 Certification Checklist, and BSL3 Certification Requirements. DOHS certification requirements for high containment (BSL4) laboratories are being compiled at the time of DRM publication and shall be available at a future date. In order to ensure compliance certification, the evaluation process must be ongoing throughout the project and the A/E shall coordinate any requirements necessary at the design stage in collaboration with the Project Officer and DOHS in order to achieve certification.

### B. Inspection and Acceptance

Contractors and Lessors are required to maintain adequate quality control systems and perform such inspections as will ensure that the work performed under the contract conforms to contract requirements. The Contractor and/or Lessor should maintain complete inspection records and make them available to the Government. All work shall be conducted under the general direction of the Contracting Officer and is subject to Government inspection and test at all places and at all reasonable times before acceptance to ensure strict compliance with the terms of the contract. Government inspections and tests are for the sole benefit of the Government and do not relieve the Contractor and/or Lessor of responsibility for providing adequate quality control measures; nor relieve the Contractor and/or Lessor of responsibility for damage to or loss of the material before acceptance; constitute or imply acceptance; or affect the continuing rights of the Government after acceptance of the completed work under the contract.

ORF is encouraged to have one or more full-time Government inspectors on large and complex construction or design-build projects; however, the presence or absence of a Government inspector does not relieve the Contractor and/or Lessor from any contract requirement, nor is the inspector authorized to change any term or condition of the contract without the Contracting Officer's written authorization.

The Contractor and/or Lessor will, without charge, replace or correct work found by the Government not to conform to contract requirements, unless in the public interest the Government consents to accept the non-conforming work with an appropriate adjustment in contract price. The Contractor and/or Lessor will promptly remove rejected material from the premises.

If, before acceptance of the entire work, the Government decides to examine already completed work by removing it or tearing it out, the Contractor and/or Lessor, on request, shall promptly furnish all necessary facilities, labor, and material. If the work is found to be defective or non-conforming in any material respect due to the fault of the Contractor and/or Lessor or its subcontractors, the Contractor and/or Lessor shall defray the expenses of the examination and of satisfactory reconstruction. However, if the work is found to meet contract requirements, the Contracting Officer shall make an equitable adjustment for the additional services involved in the examination and reconstruction, including, if completion of the work was thereby delayed, an extension of time.

The Government shall accept, as promptly as practicable after completion and inspection, all work required by the contract that the Government determines meets contract requirements or that portion of the work the Contracting Officer determines can be accepted separately. Acceptance by the Contracting Officer shall be final and conclusive except for latent defects, fraud, gross mistakes amounting to fraud, or the Government's rights under any warranty or guarantee.

## B. Warranties

1. Basic Warranties - It is in the best interest of the Government to have the entire construction project warranted. OPDIV Contracting Officers shall insert in full text FAR Clause 52.246-21, Warranty of Construction, into construction contracts as well as design-build contracts. This clause provides for the following: The contractor, whether a construction contractor or a design-build contractor, essentially warrants that work performed under their contract conforms to the contract requirements and is free of any defect in equipment, material, or design furnished, or workmanship performed by the Contractor or any subcontractor or supplier at any tier. The standard

warranty period extends usually for one year from the date of final acceptance of the work.

Contractors shall provide warranties in a separate binder with points of contact names, addresses, and all applicable phone and fax numbers.

2. Adjustments of Basic Warranty/ Guarantee Period - The contractor may request an adjustment in a warranty period based on completion of the work and use of the equipment and/or system by the Government. Systems that are utilized on a seasonal basis must be tested and used through a complete annual load cycle. For example, if the final inspection were held in the fall, the air conditioning system would not be properly tested under full load until the following air conditioning season. The contractually specified warranty period does not apply to latent defects. The timeframes in which remedies for latent defects are possible is usually much longer than the standard one year warranty.

3. Manufacturers', Subcontractors', and Suppliers' Warranties - The A/E generally specifies product performance characteristics that result in warranties. In many cases these warranties are industry standards. All warranties express or implied, from subcontractors, manufacturers, or suppliers for work performed and materials furnished are enforceable under the contract. The Contractor is required to obtain all warranties that would be given in normal commercial practice; all warranties are to be executed, in writing, for the benefit of the Government, and all warranties are to be enforced for the benefit of the Government.

   The management of the warranty process should be passed to the maintenance staff operating the facility along with COTR responsibilities. This group of individuals identifies the actual problem through troubleshooting processes and determines if it is in fact a warranty issue. Then appropriate action and follow-up can occur as well as a documented history. This staff also works with the Contracting Officer to resolve any items in dispute and provide any necessary technical information to the Contracting Officer for enforcement of the warranty requirement.

## C. Occupancy

1. Normal Occupancy - Generally, the facility is occupied after final inspection and acceptance.

2. Beneficial Occupancy - The Government has the right to take possession of or use any completed or partially completed part of the work. Before taking possession of or using any work, the Contracting Officer should furnish the Contractor a list of

items of work remaining to be performed or corrected on those portions of the work that the Government intends to take possession of or use. However, failure of the Contracting Officer to list any item of work shall not relieve the Contractor of responsibility for complying with the terms of the contract. The Government's possession or use shall not be deemed an acceptance of any work under the contract. Any unfinished work remaining punch list items in areas to be occupied, shall not cause major disruptions to the occupancy

3. Government Responsibility When beneficial occupancy is affected prior to full acceptance, a careful inspection of the area to be occupied should precede such occupancy. Since the Government would be responsible for restoration and repair of damage resulting from the beneficial occupancy, records of conditions in both photographic and narrative form at the time of occupancy are essential.

   While the Government has such possession or use, the Contractor is relieved of the responsibility for the loss of or damage to the work resulting from the Government's pos-session or use. If possession or use by the Government prior to substantial completion of the entire project delays the progress of the work or causes additional expense to the Con-tractor, an equitable adjustment should be made in the contract price, the time of completion, or both, and the contract should be modified in writing accordingly.

4. Occupancy Agreements - The Contracting Officer shall prepare an appropriate letter to the contractor setting forth the extent of the occupancy and its effective date and time. Lists of deficiencies and omissions in the occupied area should be included. In addition, when partial occupancy is required, an agreement with the contractor must be executed which delineates facility service responsibilities (maintenance, utilities, security, etc.).

# 1-13-20 Information

## A. Operations and Maintenance Manuals

Operations and Maintenance (O&M) Manuals are essential to the activation and long term care of new HHS facilities. Provisions in the construction or design-build contract should require the development of a consolidated operations and maintenance manual for the entire facility in both hard copy and electronic soft copy. A copy of the manual should be kept and maintained by the OPDIV's facilities management office and the OPDIV's operation and maintenance field office. The manual shall include:

- A copy of all warranties.

- As-built/record drawings of project
- A list of all training requirements and a roster of trainees.
- All information necessary to optimize operations and maintenance of facility equipment and systems.
- Specific operational protocols for special and highly sophisticated equipment.
- Standard operating procedures and parameters.
- Commissioning results as a baseline for validation and facility performance expectations.
- O&M shall also contain Facility Numbers of the equipment.

## 1-13-30 Reporting Requirements

### A. Laboratory Certification:

A compliance certification statement prepared by the A/E shall be required at the 95% design submittal.

# Design Considerations 2



# Section 2-1: Customers

2-1-00 Design Requirements
- 10 Design Guidance (Reserved)
- 20 Design Information
- 30 Design Document Requirements

## 2-1-00 Design Requirements

The Customer is the focus of everything we do. ORF is focused on satisfying the needs of its customers, driven mainly by its reputation for quality!

The purpose of this section is to develop NIH Programs of Requirements (POR) and other planning and programming documents and shall not be used for design review. Concept or schematic designs shall be reviewed against the POR.

## 2-1-20 Design Information

### A. Key Customers

Users: The researchers, medical personnel, administrators, support personnel and visitors who use NIH facilities on a daily basis. ORF provides and operates the NIH facilities so that it possible for the users to perform their duties or functions.

Key Administrative Officers: The principal customer contact for the Institute/Center (IC). They request facility improvements and provide the necessary requirements for the request. ORF meets the facility requirements and desires of the Administrative Officers

Scientific Directors & Executive Officers: Establish the scientific and administrative programmatic direction of the ICs. ORF implements the programmatic directions as they relate to NIH facilities.

Program Facility Managers of Accredited Facilities: Responsible for maintaining the accreditation of the facilities that they manage. ORF assist the Program Facility Managers in maintaining their accreditation by making the correction of deficiencies in accredited facilities a very high priority.

## B. A Slice of a Day in the Lab:

The following discussion is taken from a lecture given by James L. Mulshine, M.D. at the NCI-ORS/NIH, ISPE Research and Development Symposium, on March 5, 1996, "Designing for Research Ethos." This discussion is to give the programmer a flavor of research activities from a researcher's perspective. "The typical experiment conducted in today's NIH laboratory is complex. It could involve some cell harvesting, some incubations, some purification steps, some primary analysis steps, some data reduction efforts, graphical representation of results, and drafting a report. While these activities may happen within the same walls, specialized resource areas are available in other environments to perform distinct tasks more efficiently. A critical issue for each laboratory to resolve is how much space should be dedicated to specialized instrumentation as opposed to maintaining space as generic."

More than previously, instrumentation is being bundled with a dedicated micro computer on its own freestanding cart. "These instruments include beta and gamma counters, phosphor imagers, other image analysis instruments, freeze dryers, and gel dryers, to name a few. The balance between specialized space and generic space is an emerging issue in planning and obtaining optimal lab density. Control of bench space is a visceral issue regardless of the nature of the research setting."

The design for experimentation generally imposes the requirement of close time management. Time dependent access to a work space is usually required at several periods during the course of a typical experiment. In specific instances, access to related instrumentation workstations critical to the experiments may drive adjacency considerations. In some cases, instrumentation is so critical to the experiment, that redundancy is necessary, in which case both the primary and backup instrument must be equally accessible to the researcher. "To optimize the work environment in the lab, it is critical to understand its subcultures. The average research lab, especially at NIH or in academia, is tightly regulated with highly specialized instrumentation." The ambiance in the lab ranges from the ascetic to playful. A number of people rotate through the laboratory in a given year. A problem is that at NIH there is a transient population, so lab occupants may not have as a proprietary identification with their physical environment as elsewhere.

## C. Research Personnel Profiles

The following discussion is also taken from Dr. Mulshine's lecture. This discussion is about the expectation of the occupants of a laboratory. Again this is from the perspective of a re-

searcher and it provides useful anecdotal information about the behavior of occupants in a laboratory setting at a particular stage in their career.

"The personnel in a typical lab consist of technicians, students, graduate students and post doctoral fellows, staff scientists, and junior and senior faculty. All these groups have their own needs and aspirations which can result in different expectations of a research facility."

Technical Staff: "At NIH, a technical staff person is typically among the most accomplished lab workers in the world. Many of the NIH GS -11 technicians with long years of experience have accumulated expertise in a staggering array of laboratory techniques. They, along with the post doctoral fellows are the backbone of the productivity of the NIH. With experience, a technician accrues a sophisticated understanding of laboratory ergonomics." Programmers and lab design teams would profit from listening more to the thoughts of these accomplished individuals. "These people are concerned about the flow of activities. They want to have tissue culture, bench space and refrigerators in close relationships to allow efficient lab work. They want to have ample adjacent storage space to have at their disposal all the accouterments that allow them to continue working and sustaining progress through a grant or fiscal cycle. These seasoned individuals are more sensitized than others to safe lab practices, so they want good airflows and strategically placed desktop downdraft hoods. Technicians are in the lab for extended projects, so they do not want to prolong exposure to noxious substances. In their time they have seen or heard of shut downs for radioactive spill or toxic waste accidents." For this reason, they want the professionals in ORF to build into a facility the infrastructure that will allow them to stay in compliance with good lab practice. "With rapidly evolving hazardous material handling requirements, this aspect of lab design is in flux."

Students: The student's time in the lab is more temporary, so they want to see as many techniques as possible during their tenure. Students spend more time with literature searches and downloading articles and data bases than doing lab work. They want access to journals and proximity to white marker boards (white boards) and beverages. The importance of lab safety is not so deeply ingrained in them so it is best to segregate certain functions. If the journals and workstations and white marker boards are not in the lab but close by, then the chances of the beverage staying off lab benches is better. Students' curiosity leads to wandering, and they like to work in shared equipment rooms because of the novelty and the potential for encountering a fellow student. Student requirements are probably the least critical of the design qualities of the facility.

Graduate Students and Post Doctoral Fellows: The post doctoral fellows and graduate students occupy a distinct niche in the research community, and need a place to work. They

have a time limit to successfully complete their research. They are more paranoid about freezer and incubator failure. Many students need to work at odd hours through the night. They demand good logistical support so that, for example, they can find additional bovine serum albumin and a package of five c.c. pipettes at 3:00 A.M. in the morning.

"Smart building systems and lab equipment monitoring is important to these folks. These people spend a lot of time putting together respectable posters. These posters are put together in a frenzy of activity leading up to major national meetings. Small conference rooms can be temporarily converted into staging areas to facilitate poster assembly. Upon returning from meetings, mounting these trophies (posters) on hall bulletin boards allows for collegial feedback on current research projects. Interaction rooms where post docs can snack, sip coffee and gripe about the latest failed experiment are an important lab asset. Close proximity to journal racks is desirable here. Post docs like bikes and jogging so provisions for showers and access to a place to lock a bike are appreciated."

Staff Scientists: Staff scientists are career doctoral scientists who have special expertise. For example, they may run the cell sorting facility, the electron microscope or perform all the DNA or protein sequencing. The scientists need conditioned power and uninterrupted power for their expensive, specialized and sensitive instruments. They may or may not need a private office but they, along with technicians, need a place to store their coat, some lab supply catalogues and their lunch securely.

Tenure Track Faculty: "The junior faculty wants an office as much as they want their own lab modules. Even within a large lab room, if a functional boundary is devised, it helps new faculty members to feel more in control of their own destiny." This is important because cooperation in a lab is generally greater when the workers in the lab are confident that they are in control of critical variables during the day that determine their rate of progress.

Senior Faculty: "Senior Faculty spends more time on the phone and more time in conferences. They too, want white board access. They need meeting areas in close proximity with the lab to conduct lab meetings and to network with collaborators." Although they are away from the lab, its design is an important influence on them. For example, complaints of insufficient computer access and contaminated incubators fall to the Senior Faculty member for resolution. "Senior Faculty members have a long term stake in the proper functioning of the lab. From the Senior Faculty perspective, the best research facility is the one that lets the focus of the group stay on the research problem and not on the facility."

### D. Animal Care Personnel Profiles

Veterinary Assistants and Laboratory Animal Caretakers: Feed, water, and examine animals for signs of illness, disease, or injury in laboratories. Clean and disinfect cages and work areas, and sterilize laboratory and surgical equipment. They may provide routine postoperative care, administer medication orally or topically, or prepare samples for laboratory examination under the supervision of veterinary or laboratory animal technologists or technicians, veterinarians, or scientists.

Veterinary Technologists and Technicians: Use the skills of Veterinary Technologists and Technicians, who perform many of the same duties for a veterinarian that a nurse would for a physician, including routine laboratory and clinical procedures. Veterinary Technologists and Technicians may work in research facilities, where they may administer medications orally or topically, prepare samples for laboratory examinations, and record information on an animal's genealogy, diet, weight, medications, food intake, and clinical signs of pain and distress. Some may be required to sterilize laboratory and surgical equipment and provide routine postoperative care. At research facilities, veterinary technologists typically work under the guidance of veterinarians, physicians, and other laboratory technicians. Some veterinary technologists vaccinate newly admitted animals and occasionally are required to euthanize seriously ill, severely injured, or unwanted animals.

Veterinarians: Responsible for the day-to-day operation of the animal research facility. Veterinarians play a major role in the healthcare of laboratory animals. They work in basic research, broadening the scope of fundamental theoretical knowledge, and in applied research, developing new ways to use knowledge. Veterinarians can contribute to human as well as animal health. They work with physicians and scientists as they research ways to prevent and treat various human health problems. For example, veterinarians contributed greatly in conquering malaria and yellow fever, solved the mystery of botulism, produced an anticoagulant used to treat some people with heart disease, and defined and developed surgical techniques for humans, such as hip and knee joint replacements and limb and organ transplants. Today, some determine the effects of drug therapies, antibiotics, or new surgical techniques by testing them on animals.

## 2-1-30 Design Document Requirements

### A. Program of Requirements

The Program of Requirements (POR) is a customer directed document and it is essential that the customer's input is reflected in the POR.

### B. Project Definition Rating Index (PDRI)

Customer input is vital to the scoring of the project's (PDRI).

# Section 2-2: Pre-design Documents



## 2-2-00 Design Requirements

The following documentation is required and scored in the project's Project Definition Rating Index as required by Volume I Section 2-4 of the HHS Facilities Program Manual.

### A. Master Plans

The design of NIH facilities shall be in accordance with the land use and bulk regulations (massing) regulations of the local NIH campus master plan. The A/E shall evaluate the architectural compatibility with the NIH campus and NIH Master Plan objectives, functional requirements, economy of construction, energy conservation, sustainability, interior and exterior details, and life cycle costs. Facility designs shall address the needs of all users of the facility and enhance the lives of these users while providing the latest state-of-the-art features to further the goals and objectives of the NIH throughout this century.

### B. Program of Requirements

The Program of Requirements (POR) shall be in accordance with Volume I Section 2-5 of the HHS Facilities Program Manual. The end users of the research laboratory or animal research facility shall be involved during the programming and design phases to ensure the design meets the specific needs.

### C. HHS Facility Project Approval Agreement

A HHS Facility Project Approval Agreement (FPAA) is required in accordance with Volume I Section 2-3 of the HHS Facilities Program Manual. The FPAA (Exhibit X2-2-A) will document the project's scope and description, basis of need, funding source(s) and total cost from all sources. It also identifies project schedule milestones, including completion of design, construction, activation and operational phases. The agreement represents a commitment by the NIH to the requirements, scope, schedule, cost and programmatic need of the project and will be submitted with the NIH annual facilities budget submission.

### D. Topographic Surveys

The NIH Project Officer and Contracting Officer shall identify the parcel of land or site that the project is located on and have a boundary and topographic survey prepared by a licensed professional land surveyor.

### E. Utility Surveys

The NIH Project Officer and Contracting Officer shall identify all above ground and underground utilities on the site and locate utility services to the site. The NIH Project Officer and Contracting Officer shall determine if all necessary utility services are available and have adequate capacity.

### F. Environmental Documentation

The NIH Project Officer and Contraction shall ensure that the proper environmental documentation is completed and approved.

### G. Historic Preservation

The NIH Project Officer and Contracting Officer shall consult with NIH Federal Preservation Coordinator to determine if the project will affect historic property. If a project is located in the vicinity of known archaeological sensitive areas and the land has never been disturbed archaeological surveys may be required.

### H. Subsoil Investigations

The Project Officer and the Contracting Officer shall ensure that subsoil investigations and foundation recommendations are completed.

## 2-2-20 Design Information

### A. Master Plans:

Master plans for NIH sites serve as strategic planning tools for the efficient allocation of facility related resources, the orderly arrangement of future growth and development on NIH campuses, and the accomplishment of operations and maintenance activities needed for establishing a functionally and aesthetically pleasing physical environment conducive to accomplishing the mission of NIH. NIH Master plans has a significant impact on the development of NIH building programs. Master planning for NIH sites defines the physical framework for the changing nature, character, and urgency of biomedical research and education. It provides a supportive environment for the people involved in NIH activities, and protects and enhances the natural and environmental qualities of NIH sites and their surrounding communities.

Site development opportunities derive from the Master Plans. The master plans provide the framework for future development that must be adhered to if the overall campus vision is to be achieved. Site development is established in conjunction with the Master Plans. They define key elements and determine major relationships, patterns, and standards that shall be adhered to when developing site or building projects. Development guides address issues of building size and massing, site characteristics and quality, definition of open spaces, and access and circulation. All new buildings shall conform to the NIH Master Plan for the appropriate sites. The DRM addresses phased implementation of the Master Plans in a logical sequence of construction, renovation, or demolition over the life of the plan. For additional information, contact the Project Officer and go to
http://orf.od.nih.gov/Planning+and+Space+Management/NIHMasterPlanning

## B. Program of Requirements

Programming is the process of project definition where project goals are established; projects needs are determined; project facts are analyzed; and project concepts are tested all resulting in project problem statements. The programming process involves the following considerations: function, form, economy and time.

Project goals are the customers and users expectations and the programming is a cooperative process emphasizing customer/user decision making. Project needs are the projects requirements such as space, power, utilities, etc. Project facts are site constraints, site potentials, regulations that affect the project, etc. Project concepts are functional relationships, adjacency requirements, etc. Programming is finding out what the whole problem is and is the basis for a more comprehensive solution. The whole problem covers a wide range of factors that influence design.

# Section 2-3: Laboratories

2-3- 00 Design Requirements
10 Design Guidance
20 Design Information (Reserve)
30 Document Requirements

## 2-3-00 Design Requirements

The purpose of this section is to develop NIH Programs of Requirements (POR) and other planning and programming documents and shall not be used for design review. Concept or schematic designs shall be reviewed against the POR.

Space utilization of NIH Laboratories shall be in accordance with Paragraph 2-2-20.B in Volume II of the HHS Facilities Program Manual.

- Excellence in design with commitment to quality by the design and management team is a primary goal for all NIH.
- Each investigator shall be provided with adequate and comfortable laboratory space, including laboratory work space, laboratory support space, storage space, research space, and administrative support space in order to create a safe and functional research environment.
- Designs for new research facilities shall include considerations for future expansion including horizontal and vertical expansion. Building massing shall be consistent with the current master plan.
- Laboratories and offices shall be provided with natural light and views to the outside, unless it conflicts with functional requirements.
- Columns shall not fall within the laboratory planning module so as to interfere with facility space planning and laboratory layouts, and inefficient use of valuable space.
- Interstitial space shall be designed to scale. A model or full size mock up of the interstitial space is required.
- The laboratory planning module shall be considered the primary building module in multi-use facilities due to the importance of the laboratory planning module to functional and safety issues.
- Adequate laboratory work space shall be provided to meet the need for areas of lab components such as chemical fume hoods and/or biological safety cabinets (BSC), laboratory benches, equipment, storage, and desk space. The space shall be adequate to provide a safe working area, including access to and around equipment, containment devices, and bench top areas. Placing Fume Hoods and Biological Safety Cabinets in la-

boratories shall comply with the findings of the "Methodology for Optimization of Laboratory Hood Containment - Volumes I and II, November 1996, Farhad Memarzadeh, PhD, P.E., NIH – Office of the Director, ORF Publication, Bethesda, MD"

## A. Laboratory Design Requirements

A NIH laboratory at a minimum requires the following:

- A hand washing sink with an emergency eyewash.
- A safety shower where fume hoods are located or corrosives are handled as required.
- A UL rated flammable storage cabinet.
- An “INTERNALLY EXPLOSION SAFE” refrigerator if required by the program.
- A corrosive storage cabinet.

The following laboratories are typical of biomedical research laboratories.

Wet Laboratories: Wet laboratories house functions that include working with solutions or biological materials and utilize benches, sinks, chemical fume hoods, and/or BSCs. Generally, a wet lab is fitted out with a full range of piped services such as deionized or reverse osmosis (RO) water, lab cold and hot water, lab waste/vents, carbon dioxide ($CO_2$), vacuum, compressed air, hand washing sinks, eyewash, safety showers, natural gas, telephone, local area network (LAN), lighting, and power. Any wet laboratory where biological specimens are used shall require an area to store medical pathologic waste (MPW).

- Sufficient kneehole space shall be provided in each laboratory module to accommodate in use MPW boxes as well as other in use waste receptacles.
- Laboratories that use radioactive materials will require a lockable storage area for multiple radioactive waste containers including dry and liquid waste.
- Access to wet and dry ice is required for most biomedical research.
- Work areas and desk space require low bench space with kneeholes or adjustable, flexible desktop space.
- These areas may be used for a large number of computers requiring HVAC, supplemental cooling, electricity, emergency power, uninterruptible power, and/or telecommunications / LAN.

Instrument and Special Function Laboratories: These laboratories provide space for instrument and special function laboratories shall be designed and sized based on the principal instrument.

Building Operations: Separate and dedicated space in shipping and receiving areas shall be provided for animal receiving and carcass disposal if the laboratory building has animal facilities.

## 2-3-10 Design Guidance

This section will provide architects, lab planners, scientists, and administrators with the latest NIH experience with the design of state-of-the-art biomedical research laboratories. This section will discuss laboratory general research trends, activities, laboratory planning objectives, quality of life, laboratory planning parameters, distribution of services to the laboratory module, space requirements, gross area allowances, functional relationships, and laboratory planning concepts.

### A. Laboratory Research Trends

- There is a trend toward larger, denser, shared laboratory support rooms such as equipment rooms, cold rooms and special function rooms.
- Laboratory Work Space: There is a trend to locate fume hoods out of the laboratory to a more centralized and shared location.
- Biocontainment Laboratories: With the nation's fight against terrorism and pandemic diseases there is a need for more biocontainment laboratories.
- Flexible and Mobile Casework: With the need for biomedical laboratories to be more adaptable to changes in research protocols, there is a trend for casework to be mobile.

### B. Laboratory Activities

Biomedical research includes a variety of scientific disciplines that need to be accommodated in the lab space. Laboratory facilities should provide space to perform experiments, electronic monitoring and calibration, information processing and retrieval, specimen and equipment storage and recording equipment. Laboratories should be adaptable for the rapidly changing biomedical environment and should be able to support emerging scientific disciplines.

Laboratory facilities should also provide space for administrative activities and informal staff interaction. Administrative space should include offices for the laboratory chiefs and their secretarial and support staff. Areas should be provided to encourage interaction and philosophical exchange of ideas between scientists. Interaction areas may include refreshment or break areas, copy centers, meeting rooms, corridors, and terraces.

## C. Design Goals and Objectives

The NIH's goal is to provide state-of-the-art research laboratories to enhance and maintain its position as the world leader in biomedical research. The NIH accomplishes this goal by constructing new facilities and renovating older ones to meet ever changing biomedical research needs. The end users of the research laboratory must be involved during the programming of the facility to meet the various specific needs of the laboratory occupants. Program requirements for the specific project must be defined.

### C.1 Quality of Life

The laboratory should be designed for people who conduct research and it is the goal of NIH to provide them with a safe and pleasant work environment that leads to increased productivity, higher retention rates and easier recruitment of new staff. Direct natural light and view to the exterior, adequate work space, appropriate color, a coordinated and well organized layout, attractive and functional casework, and amenities such as exercise facilities, cafeterias, credit unions, bank teller machines, vending machines, shops, and child care facilities are some of the design features that will enhance the quality of life. These amenities should ether be in the facility or in close proximity.

### C.2 Natural Light:

Laboratories and offices should be provided with natural light and views to the outside, as long as they do not conflict with functional requirements. This presents design challenges with significant planning and functional zoning implications in large, multi floor facilities. Two significant issues that should be addressed when providing natural light are glare to computer screens and bench work areas and the solar effects of heat on internal temperature control. Natural light is not required in laboratory support areas such as rooms for large equipment or freezers. Laboratories utilizing photographic and optical diagnostic techniques should be located in dark areas of the facility such as interior support areas.

### C.3 Lighting:

Laboratory research requires high quality lighting for close work. Lighting intensity and uniformity should provide shadow free illumination of the laboratory work surface. The ability to control lighting in specialized laboratories or in spaces that use computers should also be considered.

### C.4 Noise:

Noise sensitive areas include, but are not limited to, space where microscopy, microinjection or other procedures that require a high degree of manual precision or metal concentra-

tion are performed. Noise levels in laboratories are difficult to control because room finishes are generally hard and nonabsorbent. Equipment such as chemical fume hoods, centrifuges, and vacuum pumps contribute to the high noise levels within the laboratory. Planning should isolate noise sensitive areas from noise sources wherever possible.

## C.5 Vibration:

Vibration caused by equipment can adversely affect the quality of life in the workplace for personnel. Structural dampening to minimize vibration is required for sensitive instruments so that scientific research is not adversely affected. Some pieces of equipment that are vibration sensitive can be placed on a special vibration dampening table or close to more vibration stable parts of the building such as at grade or near a column.

## C.6 Interaction:

Exchange of ideas in a biomedical research facility is fostered by formal and informal communication, interaction and collaboration among researchers. In addition to the desired consolidation of branch level activities, an important requirement is a building planning concept that promotes informal encounters and communications among all of its occupants. Proximity to common facilities, such as conference rooms, rest rooms, break rooms, coffee areas and vending machines, mailboxes, clerical support services and supplies encourage casual encounters and facilitate interaction. Interaction areas should be shared spaces and these spaces should be designed to draw researchers out of their labs and offices from time to time.

Careful design of circulation patterns and corridor spaces can also contribute to interaction between building occupants in all parts of a building. The designer should consider alternative informal interaction areas such as alcoves or event areas at the end of corridors where researchers can talk together without using the traditional break area; stairwells can be designed as open, well lit areas where researchers might meet going up or down between floors; elevator lobbies and general circulation corridors might have natural light and views and be large enough to provide informal seating areas. In addition, bulletin boards, directories and seating areas should be located in entrance lobbies or where there is cafeteria access. Conference rooms might open into these areas to encourage additional interaction. Another potential interactive space might be an exhibit area in a public entrance area that has adjacency to an auditorium, cafeteria or other public spaces.

## C.7 Efficiency:

Efficiency is a key element in the success of a laboratory facility. The designer should carefully consider circulation of personnel, animals, supplies and waste as well as functional relationships and adjacencies to increase the efficient use of available space.

## C.8 Graphics/Signage:

Graphics and signage will help employees and visitors find their way through a laboratory building. Directional graphics and signage should be functional and in harmony with the architecture of the building. Signs are also important for the identification of the biohazard level of areas where biohazardous work is performed. Interior signage shall be in accordance with the NIH signage manual.

## C.9 Artwork:

Artwork is not typically part of a project's construction budget, and should be selected and purchased by the user. However, creative alternatives to purchasing artwork should be considered. These may include obtaining art through various loan programs or through philanthropic donations. The design should be sensitive to user defined artwork so that adequate structural support lighting and architectural detailing are provided.

# D. General Laboratory Planning Parameters

To be successful, a laboratory building must satisfy currently programmed research needs in terms of space, environment, support services, functions and equipment. In addition, the building must also anticipate research needs which will occur in the future. The building, through proper planning, must have flexibility and adaptability to keep pace with the rapid changes continually occurring in biomedical research, grant funding cycles and recruitment of new researchers. It is essential that the design allow research space to be converted and renovated with minimal disruption.

The most important aspect of the "state-of-the-art" research facility is the ease and simplicity with which any part of the facility can respond to change. For example:

- Change in focus of research (e.g.: response to a newly threatening disease)
- Change in personnel (e.g.: size or makeup of group or team).
- Change in environment (e.g.: open space vs. enclosed space).
- Change in procedure (e.g.: wet chemistry to automated process).
- Change in technology (e.g.:  for new equipment)

With this in mind, flexibility and adaptability in the building design can be achieved through use of modularity, redundancy and accessibility from the start.

## D.1 Modular Space Planning:

Space must be carefully organized on a modular basis free of closed in stairwells, chases, shafts, shear walls, elevators and all other obstructions save regularly spaced structural columns. Modules must be organized in a manner that allows space to be easily reconfigured.

## D.2 Flexibility:

It is important that laboratory space and utility services be designed for flexibility so they can be readily adapted to accommodate future changes in research protocols. Laboratories require an enormous amount of capital to construct, and they should not be rendered functionally obsolete due to a minor change in state-of-the-art technology or research priorities. It is important that the laboratory have the ability to change without affecting adjacent research activities.

## D.3 Capability:

The laboratory building must be capable of providing all the utility services necessary for the scientists to conduct their research. It is equally important that provisions be made for future utility services to accommodate unanticipated demands brought about through improvements in technology or through changes in research protocols. Flexibility and capability can be said "to go hand in hand". Reserve capacity should be designed into the primary building utility systems to accommodate future levels of growth and change. Spare capacity should be designed into the building systems to allow researchers flexibility to add equipment and instrumentation as required to meet ever changing needs without compromising laboratory health and safety.

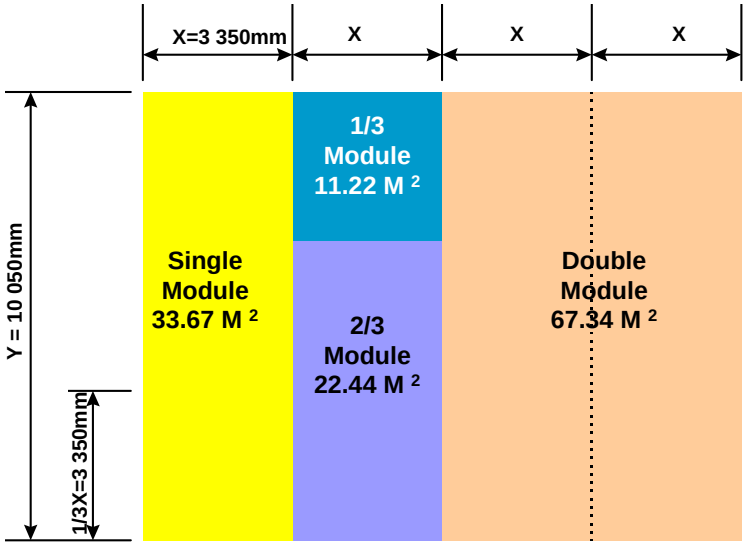
## D.4 Expansion:

In the context of master planning, future expansion is an important consideration in laboratory facilities. State-of-the-art research buildings must be designed to accommodate expansion. Establishing a framework for building systems which can be easily expanded and be consistent with the master plan is essential.

## D.5 Planning Module for Laboratories:

The laboratory module is fundamental to planning a flexible laboratory building. It provides certain regularity and repetitiveness in the size, shape and arrangement of programmed spaces. The laboratory module is the basic laboratory building block, and it must be properly sized so that assembling a number of modules can create a variety of laboratory units. Modules are combined and divided into segments to satisfy programmatic space needs. They represent planned and identified locations for certain laboratory furniture, partitions, ceiling and lighting systems, HVAC and plumbing systems, electrical power and communi-

cations distribution, etc. The laboratory module enables the design team to select and arrange building systems in a rational manner. A laboratory planned with modules permits safe, cost effective modification of building systems when future alteration of the laboratory is required, and will allow principal investigators the maximum flexibility in setting up laboratories to suit the needs of their particular research program within a standardized building matrix.




Possible Laboratory Module Configurations

Almost every researcher has a unique set of laboratory design requirements. The planning module establishes a dimensional discipline by which systems, partitions and laboratory casework can be accommodated within the existing building structural framework. The intent is to find a common space denominator that accommodates the variety of functional requirements.

The laboratory module should offer predictability and reliability in the distribution of laboratory services. As changes of use are required by changes in research direction and in procedures or equipment; partitions should be able to be relocated, doors moved, and rooms expanded into larger rooms or divided into several smaller rooms without disturbing adjacent laboratories or building utility systems.

From general experience, it is known that certain dimensions work better in the laboratory environment than others. The width of an individual laboratory module will range anywhere from 3 048 mm (10’-0”) to 3 667 mm (12’-0”), depending on the type and amount of equipment to be placed in the space. Laboratory module widths are normally determined by an

appropriate aisle width of 1 525 mm (5'-0") plus bench or equipment space on each side of the aisle 914 mm (3'-0") each side of this aisle. After discussions with investigators at the NIH regarding optimum versatility and efficiency, it was determined that an appropriate laboratory planning module width is 3 350 mm (11'-0").

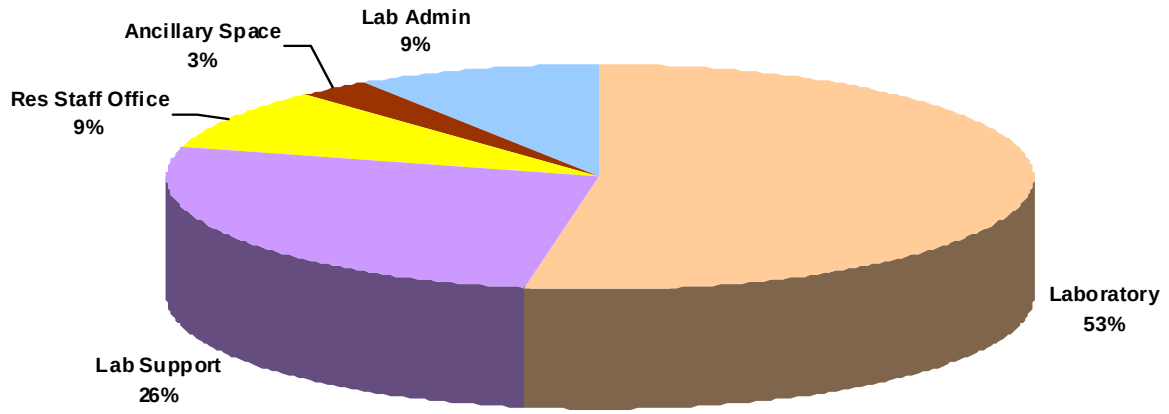
The depth of a laboratory module is determined by how many people will work at the bench the types and size of equipment to be placed in the work area, the amount of desk space, and placement and frequency of containment units such as fume hoods and biosafety cabinets. The ideal depth of the laboratory module, is 10 050 mm (33'-0")

## D.6 General Rules of Thumb for Planning Biomedical Laboratories:

The following table shows general rules of thumb to be used in planning laboratories for budget purposes, or when a laboratory program has not been developed. The data assume two persons per module. The laboratory support space is based on 50% of the laboratory.

| Space | Area ($m^2$) | Area (SF) |
|---|---|---|
| Laboratory Space | 16.50 | 181.5 |
| Laboratory Support Space | 8.25 | 90.5 |
| Research Staff Office | 2.79 | 30.0 |
| Ancillary Space | 0.84 | 9.0 |
| Laboratory Administration | 2.88 | 31.0 |
| Optimal Area per Researcher Assigned Bench Space | 31.26 | 342.0 |

The U.S. Department of Health and Human Services' utilization rate for laboratories is 200 to 460 net square feet (nsf) per person. The total area per person in the table above is 342 nsf.




Space Utilization Chart (Rules of Thumb)

These rules of thumb do not take into account levels of seniority. They also do not include areas for special function labs such as NMRs or laser labs. They also do not include animal facilities. Areas for these functions must be added to, and considered, in the overall budget and program formulation.

## D.7 Gross Building Area

The gross building area includes the total area of all floors, including basements, mezzanines, penthouses, mechanical and electrical spaces, and enclosed loading docks. Gross area is measured from the exterior surfaces of all enclosing walls except where the exterior wall surface overhangs the exterior window surface by 300 mm (1'-0") or more. In this case, the gross area is measured from a point one-half the distance between the exterior plane of the window glazing and the outermost plane of the wall. Shaft type elements such as atriums, stairs, unenclosed floor openings, elevators, escalators, dumbwaiters, lifts, mechanical and electrical shafts, are included in the gross area for one floor only. The gross building area will exceed the net area by a grossing factor. A range is given for these factors, depending on design choices for internal circulation patterns, interior partitions, utility distribution and mechanical equipment configurations. For research laboratories a grossing factor of 1.54 to 2.00 is typical.

## E. Distribution of Services to the Lab Module

In order to function properly, laboratories require the services of many utilities. The choice of design and locations of the utility distribution system(s) is a product of utility function, cost effectiveness and ease of access for maintenance, additional future services, and remodeling during the life of the laboratory.

## E.1 Systems Access, Organized and Integrated Right-of-Way:

Ease of maintenance, repair and change mandates readily accessible spaces and systems to minimize costly and time consuming disruption of ongoing research activities. Ease of accessibility should be integrated into the building-planning concept and fully coordinated with other major mechanical, plumbing, electrical and communication systems. All utilities, including communication and information systems, should be carefully organized into specific zones, both horizontally and vertically, to provide a uniform distribution of services to each lab module and to ensure maximum flexibility.

## E.2 Connection of Utilities to Laboratory Modules:

Laboratory services must be distributed to each individual laboratory module, and the connection point of each service should be in a uniform position relative to the module and detailed to provide simple extension into the laboratory without disruption of adjacent modules. These services may run in service corridors or in interstitial space allowing laboratories to change without increasing or upgrading capacity or location of central infrastructure systems. Changes would be primarily to terminal systems, i.e., piping and power connections to apparatus and equipment within the space. Appropriate valving and disconnects shall be provided by planning modules to facilitate future modifications.

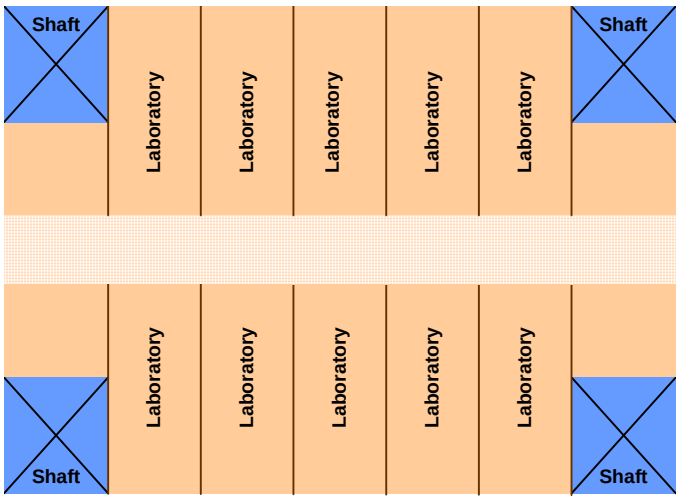
## E.3 Structural Columns:

Structural columns should be kept out of the laboratory zone and be designed consistent with the planning module. Every effort should be made to exclude structural columns from within laboratory functional space or where unavoidable, locate them so as not to interfere with the laboratory equipment, circulation areas and flexibility considerations.

## E.4 Alternate Services and Systems Distribution Concepts

Utilities and services including communication and information systems should be organized into specific zones, both horizontally and vertically, to provide uniform distribution of systems and services to each lab module and to allow for ease of maintenance and access of services and provides for maximum operational flexibility. The following identifies several concepts that have been used on NIH campuses. There are advantages and disadvantages to each system. The current trend at NIH is to use interstitial space.

Ceiling & Shaft Distribution: In this system vertical distribution of utility service is via vertical shafts, and horizontal distribution is through ceiling space to the laboratories. The services are fed down to the work area except in the case of gravity drainage; where the service is fed back down from the work area.



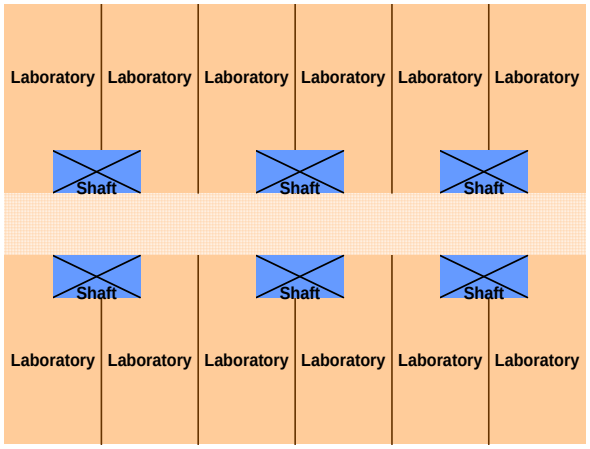

Advantages

- Useful in renovating older facilities.

Disadvantages

- Extensive ceiling space is needed.
- Ceilings must be removed for access
- Servicing could disrupt the users.

Multiple Internal Shafts: In this system vertical distribution of utility service is via smaller vertical shafts and horizontal distribution is through the ceiling space.



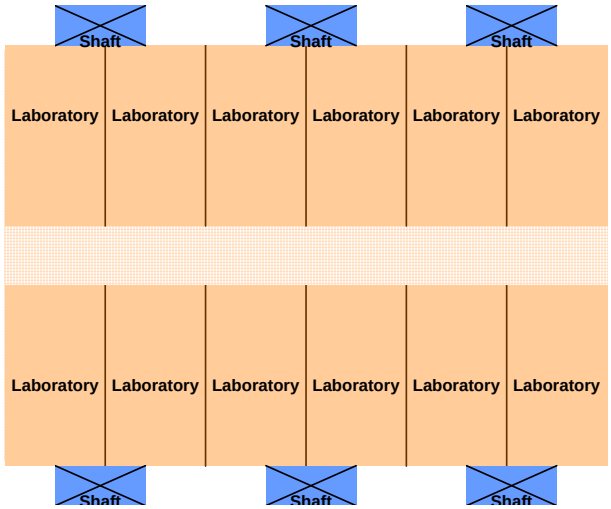

Advantages

- Relatively short horizontal runs are necessary that require smaller ducts and pipes.
- Access to shut off valves is more convenient and less disruptive than when located in ceilings
- Requires minimal floor-to-floor height in new facilities
- Suitable for alterations to existing facilities with low floor-to-floor heights

Disadvantages

- The shafts constitute multiple obstructions
- Future service additions are awkward
- The planning efficiency is decreased and the grossing factor is increased

Multiple Exterior Shafts: Distribution via multiple exterior shafts is similar to that with multiple interior shafts.



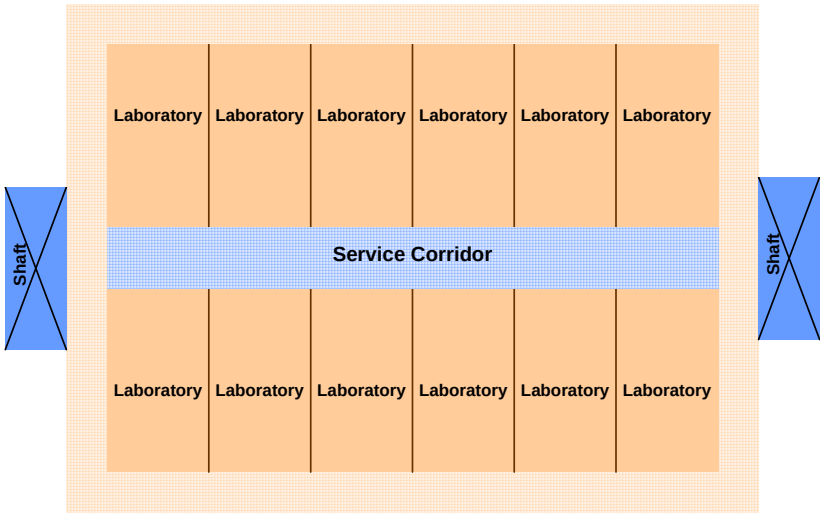

Advantages

- Relatively shorter horizontal runs are necessary that require smaller ducts and pipes
- Access to shut off valves is more convenient and less disruptive than when located in ceilings.
- In new facilities a minimal floor-to- floor height is required
- It is suitable for alteration to existing facilities with low floor-to-floor heights
- It is suitable for renovations where the introduction of new internal shafts is difficult.
- Exterior shafts increase the planning efficiency and raise the grossing factor.

Disadvantages

- It is difficult to add utilities.
- The exterior appearance of the building is strongly influenced
- Access for servicing is limited to the common wall between shaft and building.
- Piped services are subject to temperature differentials, so insulation of the shaft may be required.
- Flexibility of planning for future laboratory configurations may be reduced.

Service/Utility Corridors: In this system, laboratory spaces adjoin an accessible service corridor which houses horizontal utility services above head height and distributes horizontally into the laboratories via the ceiling or directly to the lab bench through the wall of the service corridor. Vertical shafts for mechanical and piping systems are required at strategic locations. The service corridor should be a minimum of 1 500 mm in width, plus any utility and storage areas. In a utility corridor distribution of utilities is provided through an internal dedicated corridor that accommodates maintenance staff access only.



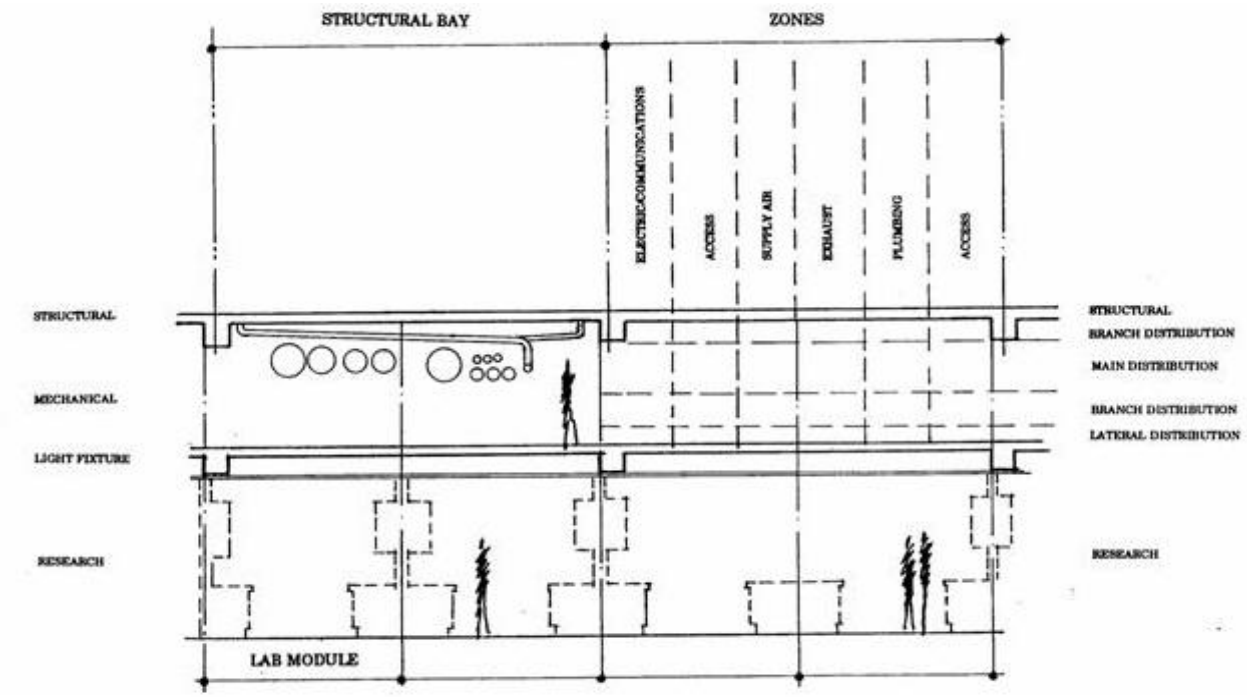

Advantages

- Continuous access for maintenance is available through the service corridor without entering research spaces.
- Shut off valves and electric panels are easily accessible.
- Special zones in service corridors could house equipment that is objectionable in the lab environment due to heat, moisture, noise, and other products

Disadvantages

- The planning efficiency is decreased and the grossing factor is increased
- Building flexibility is limited
- If the service corridor cannot be made suitable for personnel circulation or egress, the plan will require additional circulation space.
- It is more difficult to provide direct natural light into the laboratory, unless there is only one double load service corridor per floor.
- During emergencies (chemical spills, smoke and fire situations, etc.) it is almost impossible to perform a thorough clean up due to inevitable storage in the service corridor. The width of the service corridor impacts greatly on emergency response; the wider the corridor the more material that will accumulate there.

Interstitial Space: Interstitial Space is essentially an unobstructed open area with structural



columns placed where they favorably relate to the planning module. Horizontal distribution of utility systems is housed in an accessible and occupied space above the ceiling plane. The services drop vertically from the interstitial space into the laboratory. Vertical shafts at the perimeter or in a central core connect the interstitial space with the entire building. Interstitial space should be carefully designed in zones. The vertical zones consist of the following: structural zone, branch distribution zone (for utilities that are distributed through the floor such as waste lines), main distribution zone, branch distribution zone (for utilities that are distributed through the ceiling), and lateral distribution zone. The horizontal distribution zones consist of the following: electrical/communications zones, supply air zone, exhaust zone, plumbing zone, and access zone.

| Advantages | Disadvantages |
|---|---|
| • The labs enjoy unobstructed floor plan and infinite adaptability of space.<br>• Minimum disruption occurs in the lab during routine maintenance and alterations.<br>• Service is available from above or below at any point on the planning module.<br>• This system is cost effective over the life of the building. | • The volume of the building increases.<br>• The space requires additional structure for floors, catwalk, etc. |

## F. General Staffing Patterns of an NIH Laboratory

The number of staff in any laboratory varies according to type of research and can vary greatly. At NIH on average, there are 30 research personnel per laboratory. Laboratories are divided into branches and sections. There is a hierarchy of lab chiefs, branch chiefs, and section chiefs supervising each component. The size of each laboratory, branch and section should be determined early in the planning process in order to determine the amount of space to be allocated. For planning purposes, it can be assumed that there will be one to two principal investigators and/or senior scientists per laboratory. Each laboratory will have a small clerical support area consisting, on average, of two clerical personnel. The clerical support area should be of adequate size to accommodate files, copy machines, mailboxes, desks and computers.

## G. Space Descriptions

Laboratories at NIH are generally classified as wet or dry. A wet laboratory requires working with solutions utilizing benches, sinks, etc., with fully piped services. A dry laboratory involves working with electronics and large instruments with few piped services; however, more special electrical services may be required than in wet labs. No two individual laboratories operate alike. Each reflects the user's work habits and special interests. Certain

types of work require special types of tools and equipment; however, there are many features in laboratories that will be common to all despite the unique use of the space.

Laboratory buildings should be designed as generic type laboratory space whereby the future users would adapt the generic laboratory to suit their requirements by placing equipment and work zones according to their individual needs. Generic laboratory design could be used to accommodate a variety of biomedical research. With minor adaptations and well designed support space, research such as virology, immunology, physiology, cell biology, and clinical research could be accomplished in generic laboratories.

## G.1 Biomedical Laboratories

Biomedical laboratories include: biology, biochemistry, cell biology, microscopy, molecular biology, and pathology. Biomedical laboratories are distinguished by support space that is required for each laboratory or group of laboratories. Support space houses either shared equipment, such as centrifuges, refrigerators and freezers; or functions that need to be separated and enclosed for environmental or safety reasons such as: cold rooms, warm rooms and containment laboratories; or spaces that house specialized functions, such as tissue culture, chemical or infectious research laboratories. Autoclaving is appropriately conducted in support space. A well designed and strategically located support space is critical to a successful biological laboratory. The support space should be designed using the same design principles as are used in the laboratory, i.e. the same planning module.

Another distinguishing feature of biomedical laboratories is their need for proximity to live research objects such as vivariums (animal housing) and clinics for human subjects; however this is not always the case.

The desk space for the scientific staff is very important. All laboratory staff should be provided with 1.5 m (5'-0") of desk length within the laboratory module, physically separated from the laboratory bench. The desk space does not have to be in the laboratory, as long as it is reasonably close to it.

Environmental requirements, piped services, electrical services, finishes and furnishing considerations will vary from the generic biomedical laboratory. Fume hoods and biosafety cabinets (BSC) are used in all disciplines of biomedical research. The best resource for the design of specialized needs is the scientist. It is the architect's and the design team's responsibility to design these special spaces within the context of the building and the design

parameters of the mechanical and electrical systems. Storage of chemicals (solvents, flammables and acids) must be provided in accordance with applicable Federal Regulations.

Materials (cabinetry, shelving, flooring and etc.) used in biomedical laboratories should be of the corrosion resistant variety. To facilitate cleaning and combat the growth of bacteria as well as provide surfaces for radioisotope work, non-absorbing materials such as stainless steel sinks, epoxy and acid resistant plastic laminates are recommended. It is necessary to seal all casework, to prevent contamination of inaccessible space. Services associated with biomedical laboratories are: potable water (for eyewashes only) and industrial cold and hot water, drain waste and vent (DWV), deionized or distilled water, carbon dioxide ($CO_2$), vacuum, compressed air, gas, telephone, local area network for computers and electric power.

Biochemistry: Biochemistry is the study of the chemical, molecular and physical changes that occur within living organisms. The laboratories described in this section include those whose functions are mostly biochemical in nature. Large equipment used in biochemistry laboratories include multiple refrigerators and freezers (-20$^{O}$ C, -70$^{O}$ C, and -135$^{O}$ C), possibly some undercounted refrigerators, and a large number of bench top and floor model centrifuges that may require special electrical services. Connections for reverse osmosis water should be available at each sink with a shelf and outlet for a water polishing unit. Bench top space is needed for many pieces of smaller equipment that might include multiple water baths, mass spectrophotometers, and balances. Vacuum pumps may also be needed. Both flammable and corrosive chemical storage space is required. Access to a 4$^{O}$C cold room, chemical fume hoods, BSCs, and a decontaminating autoclave may be required.

Molecular Biology: Molecular biology is the study of the physical and chemical makeup and development of biological systems at the molecular level. In addition to the requirements listed for a biochemistry lab, a molecular biology lab also requires non-automatic defrost freezers for storage of restriction enzymes. Space may be needed for free standing robotic instruments. A great deal of bench space for equipment such as tabletop centrifuges, water baths, sequencers, protein synthesizers, thermocyclers for PCR reactions, automatic pipetters and robotic analysis equipment is required. Access to environmental rooms, bacteriological incubators, shakers, darkroom with an automatic film processor, microscopes and microscope table with kneehole may be needed. Radioactivity of different types and concentrations are used in molecular biology labs. Shared isolated rooms to manipulate radioactivity may be required.

Cell Biology: Cell biology is the study of the structure, function and development of individual living cells and their relationship to other living cells. Cell biology laboratories require tissue culture rooms in addition to laboratory bench space to conduct research experiments. In addition to the requirements listed for a biochemistry lab, a cell biology lab requires

access to BSCs with dual stacked $CO_2$ incubators, autoclave, cold room, and bottled liquid nitrogen. Cell biology labs may be associated with tissue culture labs, molecular biology labs and electrophysiology labs.

Tissue Culture Laboratory: A tissue culture laboratory is used primarily to support Molecular Biology and Cell Biology research. A tissue culture laboratory is often a shared space that includes multiple BSCs, multiple stacked $CO_2$ incubators with central $CO_2$ access as well as secure storage for back up $CO_2$ tanks, an adjacent sink, deep shelf storage space for plastic ware storage, a refrigerator in the room, a table top centrifuge, and a microscope bench. There should be a small amount of working bench space near the sink to prepare media. Easy access to ice rooms, cold room storage, large centrifuges, an autoclave, and liquid nitrogen freezer storage may also be required.

Pathology: Pathology includes the disciplines of histology (tissue preparation and examination), hematology, chemistry, serology, virology, and immunology. Any or all of these disciplines may be used in conjunction with cell biology labs or molecular biology labs in addition to lab functions related to an animal facility or a clinical facility. Many types of analytical instruments are used in a pathology lab. In addition to the requirements listed for a biochemistry lab, access to an autoclave is also required. A downdraft table may be needed. In addition to standing height bench space, low bench space with kneeholes will be needed for microscopes. Pathology is the "dirtiest" part of the laboratory. Locate at the end of the "clean" areas and adjacent to the "dirty" circulation path and provide negative pressurization.

Anaerobic Chamber: An anaerobic chamber is an airtight bacteriologic cell culture piece of equipment provides an oxygen free environment. Old versions were specially constructed steel chambers with an adjacent control and monitoring room and a small cold room located within the chamber. Anaerobic Chamber rooms are rarely used anymore. A less expensive alternative is a self contained windowed anaerobic chamber glove box that has external controls. A source of nitrogen and hydrogen is required to create the appropriate internal anaerobic atmosphere. Sound control for vacuum pumps and nitrogen recirculation blowers is required.

Fermenter: The fermenter is used for the production of bacteriological cultures that may generate odors, vibration, spills and other wet problems. Therefore, consideration should be given to avoiding locations above occupied space. In addition to the fermenter, the space must accommodate computer components and centrifuges. A fermenter prep laboratory is a typical biochemistry laboratory with a cold room and/or a warm room that is located adjacent to the fermenter.

## G.2 Chemistry Laboratories

Organic Chemistry: Organic chemistry is the study of carbon compounds. All biological material is made up of carbon compounds. Flammable substances, solvents, corrosives and highly odiferous chemicals may be used in an organic chemistry lab. In addition to the requirements listed for a biochemistry lab a chemical fume hood for each investigator is required. Cleanup sinks with a means of ventilation, and acid resistant waste piping is required. Areas for storage and distribution of gas cylinders that are easily accessible to the laboratory through a central or manifold system are required. Flammable and nonflammable and hazardous chemical storage areas are required. Materials used in an organic chemistry laboratory should be corrosion resistant. Counter tops, sinks and drain waste and vent (DWV) should be acid and solvent proof.

Physical Chemistry: Physical chemistry involves the analysis of the physical properties and behavior of chemical systems. Materials used in a physical chemistry laboratory are similar to those used in an organic chemistry lab. A physical chemistry laboratory typically has large electrical demands for equipment. Power ranges from 110 V and 208 V up to 480 V. Increased floor loading capacities and higher ceilings may be required for special equipment. Floor space for equipment should be accessible from four sides, is often required. The floor space is occupied by complex machinery, some of which may require direct piped services such as cryogenic gases as well as electrical power. Services associated with physical chemistry laboratories are lab cold and hot water, deionized water, DWV, vacuum, compressed air, $N^2$, gas, and electrical power. In addition, the services might include a means to distribute a cooling water system, liquid nitrogen, and high pressure air.

### Summary Space Schedule for Biomedical and Chemistry Laboratories

(* Scientist or other personnel)
Note: The area in the schedule is based on two scientists per module.

| Space Name | $M^2$ (SF) per Person* | Equipment/Furniture and Requirements | Hgt. m (ft) |
|---|---|---|---|
| Biochemistry | 16.50 (185.5) | Equipment/furniture: fume hood and/or BSC, epoxy sink w/eyewash, drying racks, tall storage cabinet, cylinder restraints, case work with acid proof work surfaces w/shelves, refrigerator, freezer, under-counter refrigerators, flammable liquid storage cabinet, corrosives storage cabinet, bench top centrifuges, desk and chair, recycle bins and safety shower. | 3.0 (9'-6") |
| | | Recommended Laboratory Shared Support Requirements: $4^{o}$ c cold room, free standing equipment room and ice support room | |

| Space Name | $M^2$ (SF) per Person* | Equipment/Furniture and Requirements | Hgt. m (ft) |
|---|---|---|---|
| Molecular Biology | 16.50 (185.5) | Equipment/furniture: fume hood and/or BSC, epoxy sink w/eyewash, drying racks, tall storage cabinet, cylinder restraints, case work with acid proof work surfaces w/shelves, refrigerator, freezer, flammable liquid storage cabinet, corrosives storage cabinet, desk and chair, recycle bins and safety shower. In addition, provide for incubators and shakers, freezers, and dry and liquid waste storage w/ Plexiglas shielding for radioisotope waste. Space may be needed for free standing robotic instruments.<br>Recommended Laboratory Shared Support Requirements: dark room, radioactive workroom and free standing equipment room | 3.0 (9'-6") |
| Cell Biology | 16.50 (185.5) | Equipment/furniture: BSC, epoxy sinks w/eyewash, drying racks, tall storage cabinet, casework with low bench, deep shelves, acid proof work surfaces, refrigerators and freezers, flammable liquid storage cabinet.<br>Recommended Laboratory Shared Support Requirements: auto clave, cold room, standard ice support, and low bench support | 3.0 (9'-6") |
| Tissue Culture | 16.50 (185.5) | Equipment/Furniture: BSCs, multiple stacked $CO_2$ incubators with central $CO_2$ back up $CO_2$ tanks, an adjacent sink, deep shelf storage space for plastic ware storage, a refrigerator in the room, a table top centrifuge, and a microscope bench. There should be a small amount of working bench space near the sink to prepare media. | 3.0 (9'-6") |
| Pathology | 16.50 (185.5) | Equipment/furniture: fume hood or BSC, epoxy sink w/eyewash, drying racks, tall storage cabinet, cylinder restraints, case work with acid proof work surfaces w/shelves, refrigerator, freezer, under-counter refrigerators, flammable liquid storage cabinet, bench top centrifuges, down draft tables, desk and chair, recycle bins and safety shower.<br>Recommended Laboratory Shared Support Requirements: autoclave $4^{O}$ c cold room, free standing equipment room and ice support room | 3.0 (9'-6") |
| Anaerobic Chamber | Equipment determines the size | Equipment: Self contain widow anaerobic chamber glove box, storage space for gas tanks and other wet lab equipment as needed. | Equip't determines the height |
| Fermenter | Equipment determines the size | Equipment: Specially constructed fermenter, computer components and centrifuges. | Equip't determines the height |
| Organic Chemistry | 16.50 (185.5) | Equipment/furniture: fume hood/investigator, epoxy sink w/eyewash, drying racks, tall storage cabinet, cylinder restraints, case work with epoxy counter tops, acid proof work surfaces w/shelves, refrigerator, freezer, flammable liquid storage cabinet, corrosives storage cabinet, desk and chair, and safety shower. | 3.0 (9'-6") |
| Physical Chemistry | 16.50 (185.5) | Equipment: Provide for several pieces of large equipment with special electrical and HVAC requirements. Provide for heavy floor loading, and high ceiling clearance. | Equip't determines the height |

## G.3 Instrument and Special Function Laboratories

Many special function laboratories require specialized analytical or observation space that is dry lab in nature. However, sample preparation is usually done in an adjacent wet lab. The instrument is the important element in an instrument laboratory. The instrument size and type, rather than personnel or bench needs, will often determine the size of the laboratory. Increased floor loading capacities and higher ceilings may be required for special equipment. Evaluation of the instrument should be done during the programmatic phase of design to ensure that there is no adverse impact by grouping the special function laboratories together. Special function laboratories include but are not limited to areas that house the following instruments: confocal microscope, electron microscopes, electrophysiology racks, electron spin resonance spectroscopes, fermenters, flow cytometers or cell sorters, lasers, mass spectroscopes, nuclear magnetic resonance imaging equipment, and x-ray crystallographers.

Highly calibrated electronic equipment may require accurate instrument dependent temperature and humidity control, stable structure, rigid vibration or local vibration dampening control; shielded space, filtered chilled water and the availability of "clean" electrical power. Vibration control is critical for most special function laboratories. Those laboratories that are vibration sensitive should be grouped together wherever possible in the overall design of the facility. See Structural Section 5-2-00-C “Vibration.” It is important that the laboratory be designed to provide easy access to the apparatus for maintenance and/or calibration. The spaces housing specialized laboratory equipment shall be designed per manufacturer’s data requirements to the apparatus for maintenance and/or calibration.

Electrophysiology/Biophysics: Electrophysiology laboratories are concerned with the study of electric impulses through tissues or cells. Electrophysiology laboratories can be either an instrument (dry) laboratory or a wet laboratory. Electrophysiology laboratories are electronics intensive. These laboratories must be vibration stable so as not to compromise highly sensitive experiments. Heavy vibration stabilizing air tables may be needed, but ideally a high degree of structural vibration stability is required. Lighting controls are required. Dark rooms or light tight rooms may be required either as adjacent space or as actual working space and should be determined with the user. Imaging rooms will be associated with the electrophysiology area. The imaging rooms may have special requirements such as attachment grids at the ceiling. The room may need to be painted black. Imaging rooms will contain optical tables that will require wider light tight doors in order to get the tables into the room. Special ventilation is needed in these labs to distribute airflow to minimize flux/area.

Typically, a large number of electronic racks will be needed with minimal bench space. However, a wet lab prep room for dissection and terminal surgery should be adjacent to the electronic rack area. The surgery will require downdraft tables, fume hoods and bench areas with air, gas and vacuum, and sinks with RO water, High pressure compressed air and nitrogen may be required. Electric power may require isolation transformers and/or special grounding. Services may include nitrogen, other gases, and high pressure compressed air. Some of the instruments used in an electrophysiology lab include microscopes, air tables; recording electronics; oscilloscopes; micromanipulators, recording pipette fabricators, vibrotomes for slicing, cameras, balances, confocal scanners, and high power lasers.

Electron Microscope: Electron microscope (EM) laboratories are concerned with evaluating tissues and/or cultures at the sub cellular and molecular levels as well as imaging of atomic structures, viruses and their components. The microscope typically is the hub of the laboratory, which must be housed in a closed room. A higher ceiling will be required for equipment. Immediately adjacent space is required for microscope components such as chillers, compressors, pump, etc., that are noisy and/or dirty, as well as for ancillary equipment such as vacuum evaporators with similar operating characteristics that dictate isolation. Adjacent space is also required for the preparation of fragile or sensitive specimens (such as cryospecimens), for ultramicrotomy, or both. An additional sample preparation area, essentially a biochemistry laboratory with fume hood, is needed to support chemical aspects (fixation, staining, embedding, etc.) of specimen preparation. In most cases, the EM laboratory will further be associated with a typical biochemistry, physiology or molecular biology lab. Lastly, the lab will require easy access to a negative and print darkroom and to a graphics/print layout room that increasingly will be a computer graphics space.

The electron microscope must be isolated away from dynamic ferrous masses such as elevators, and from vibration. Low impedance clean ground power supply to the microscope should be provided. High voltage, multiphase electric services may be required. LAN connections are required to network computers supporting the EM. Cooling water supply and return (both city and house chilled) for equipment is normally required. The electron microscope laboratory must be light tight with variable room lighting; heavy, concentrated floor loading must be accommodated. Humidity and temperature control may be required, and air distribution around the microscope is critical to equipment performance. Laminar airflow is preferred; other methods may be used as long as air is not directed toward the column. Provision should be made for storage and distribution of cylinder gases and liquid nitrogen within the lab or immediately outside the lab.

Confocal Microscope: The confocal microscope employs a laser and an optical path using a pinhole to remove out-of-focus fluorescence. This results in images with extraordinarily shallow depth of field that can be used to generate three dimensional image reconstructions of specimens. To function optimally, the room housing the confocal microscope must have space both for computers to analyze the fluorescence information obtained by the microscope, and VCR's for collecting and storing confocal information. Such a facility requires a graphics and printing area and an area for sample preparation. Confocal microscopes can be placed on an isolation air table and should be located in an area isolated from vibrations. The confocal microscope room must be properly ventilated to avoid buildup of ozone generated from the microscope's laser and mercury lamps.

Laser Laboratories: Laser laboratories are concerned with utilizing concentrated light to study and evaluate a wide range of biomedical research such as reaction of light in cells and compounds, etc. A laser suite might include the laboratory housing the instrumentation, office space and an equipment room. A sample preparation area must support the laser laboratory. The sample preparation area is an organic chemistry laboratory that will include a fume hood. The laser laboratory must be isolated from vibration; it must be light tight; heavy concentrated floor loads must be accommodated; provision should be made for storage and distribution of cylinder gases within the lab or outside the lab; high voltage electric services may also be required. Rooms where laser equipment is used must be properly ventilated to avoid buildup of ozone generated from the laser and mercury lamps. Avoid reflective surfaces.

Electromagnetic Instruments: Nuclear Magnetic Resonance (NMR), & Electron Spin Resonance Spectroscopy (ESRS) and other high powered magnets that are used to create images of living specimens have very specialized requirements. The designer must work closely with the end users and the manufacturers to determine the details for the instruments to be placed in these spaces. This will include a determination to provide an oxygen depletion alarm to warn personnel of a quench event. The magnetic field (gauss fields) created when some of these instruments are in use must be shielded from other equipment from the users, and from the general public. Partitions constructed of nonferrous building materials must be provided within the magnetic field and specialized exhaust venting should be considered. Electromagnetic instruments must be isolated away from dynamic ferrous masses such as elevators. Special acoustical design features may be required to mitigate the transfer of sound and vibration through the structure to adjacent areas.

Pits may be needed for the larger pieces of equipment. Access and clearance, both vertical and horizontal, around the equipment must be carefully planned for both equipment requirements and delivery. The weight and size of these instruments may require that they be lowered into their resting place by crane and through a specially designed well outside the footprint of the facility. Alternatively, wide access doors should be provided and tracks may be required to slide the units into place. Special cooling requirements will have to be determined based on the specifications of the instrument. Electromagnetic suites may include cold rooms, computer work areas, storage for gas cylinders, and a subject and sample preparation space. Office space may be required within the suite.

X-Ray Crystallography: X-ray crystallography laboratories are used to study three dimensional properties of molecules and compounds and the structure of proteins and nucleic acids at the atomic level. The laboratory will require light, temperature, and humidity controls. A suite may include a basic biochemistry laboratory with a fume hood for protein purification and crystal growing. A dark room, and a computer graphics/modeling room, office space, tape storage area, and a computer room will also be needed. Vibration isolation, cooling water supply and return to specialty equipment may be required and electrical low impedance and clean ground should be provided.

Mass Spectrophotometry (MS): Spectrophotometry is the process by which the ability of atoms to either absorb or emit light is measured. The MS laboratory will feature a sample preparation laboratory (chemistry laboratory or an instrument laboratory) that houses the mass spectrometer, computers, consoles, etc. Vibration isolation and a clean electrical ground may be required. Stray magnetic fields may affect equipment performance. High noise levels are generated in these labs due to vacuum pumps. Noise reduction and isolation methods should be provided wherever possible. Provision should be made for storage and distribution of cylinder gases within the lab or from outside the lab. Local point exhaust at equipment may be required.

Flow Cytometry: Flow cytometric analysis consists of pushing cells (one by one), under pressure, through a small orifice so they can be passed in front of one or two laser beams. These lasers are designed to emit specific wavelengths of light and can be used to excite fluorescent molecules on the cells. The resulting fluorescence can be measured using photomultiplier tubes and converted to electrical impulses that are stored on computers for analysis of data. A flow cytometer or cell sorter (fluorescence activated cell sorter or FACS) is a free standing instrument that can be housed in an equipment room along with its associated equipment such as computers, microscope, temperature controlled water circulators and refrigerators. Because of the heat generated by the lasers and computers, adequate cooling of the lab is essential.

Robotic Equipment Rooms: Robotic equipment is designed to eliminate human error and the monotony of performing repetitive tasks. Robots are able to process hundreds if not thousands of repetitive micromanipulations and sample transfers in short periods of time. Some robotic equipment such as a PCR thermocycler can be placed on a bench top. Many laboratories have a large number of thermocyclers or other relatively small pieces of equipment that are used simultaneously. Total power capacity should be enhanced to allow for greater flexibility and increased future usage. User needs should be considered in planning the location and spacing of electrical outlets.

Most robots are compatible with standard depth lab benches, though some robots housed on lab benches will require greater than standard depths. Other robots are very large free standing units that may require access from all sides and electrical connections from above or below. In general, a room housing robots should have good control of temperature (about 20$^{O}$C) and humidity (about 50%). Robots that need better control than the room can provide have inboard units to regulate humidity. Large heat generating refrigerators or freezers are often in the same room as the robots. This may complicate the heat control for the robots and should be taken into consideration in the planning process. Robotic laboratories require flexible RO water supply and waste plumbing installation because the robots have built in automatic liquid supply systems. High pressure air or vacuum may also be required.

Almost all robots are computer controlled. Some units have integrated central processing units (CPU) controllers within the instrument, while others have stand alone systems. The laboratory should be designed with the flexibility to provide space near the robot for the stand alone systems without using storage or bench space that is needed for other purposes.

Sequencers, which are usually bench top size, typically require venting to the fume hood exhaust system, as do DNA and protein synthesizers. Most laboratory designs require that the laboratory be under negative pressure with respect to the outside rooms, corridors or other public areas. The exception will be a room designed for genomic DNA analysis by PCR. When the program calls for a genomic analysis laboratory, it should be positive with respect to surrounding spaces. This is a critical element in genomic DNA analysis. To prevent this lab air from entering the adjoining spaces, an anteroom that is positive to genomic analysis lab and negative to adjoining spaces, must be installed. Synthesizers also generate toxic waste that has to be picked up and disposed of as chemical waste. Most other liquid handling robots don't generate toxic waste. Some robots are very noisy when in operation and may require a dedicated room with acoustical separation.

# Summary Space Schedule for Instrument Laboratories and Special Function Laboratories

| Space Name | M² (SF) per Person | Equipment/Furniture and Requirements | Hgt. m (ft) |
|---|---|---|---|
| Electrophysiology/Biophysics Suite | 16.50 | Equipment/furniture: Electronic racks, desk, sink, eyewash emergency shower, flammable liquid storage cabinet, radioactive storage & casework. | 3.0 (9'-6") |
| Electron Microscope Laboratory Suite | Equipment determines the size of the space. | Equipment: electron microscope, generator, power supply, water chiller, air compressor and nitrogen.<br>Biochemistry Prep Lab is Recommended | 3.0 (9'-6") |
| Confocal Microscope Laboratory Suite | Equipment determines the size of the space. | Equipment: confocal microscope, computers, VCR's. | 3.0 (9'-6") |
| Laser Laboratory Suite | Equipment determines the size of the space. | Equipment: lasers, sink, bench and curtains.<br>Biochemistry Sample Prep Lab is Recommended | 3.0 (9'-6") |
| Electromagnetic Instruments: MRI, NMR, ESRS Laboratory Suites | Equipment determines the size of the space | Equipment: magnet, console, terminal & UPS.<br>Biochemistry Sample Prep Lab is Recommended | ** |
| X-Ray Crystallography Laboratory Suite | Equipment determines the size of the space. | Equipment: Rotating-anode generator w/ area detectors, rotating anode generator w/ cameras, small molecule diffractometer & crystallization equipment. The computer room will be equipped w/ 2 micro processors.<br>Biochemistry Sample Prep Lab is Recommended | 3.0 (9'-6") |
| Mass Spectrometry Laboratory Suite | Equipment determines the size of the space. | Equipment: mass spectrometer data system, line printer, cooling bath, local exhaust ventilation and transformer.<br>Chemistry Sample Prep Lab Recommended | 3.0 (9'-6") |
| Flow Cytometry | Equipment determines the size of the space. | Equipment: flow cytometer or cell sorter FACS computers, microscope, local exhaust ventilation, temperature controlled water circulators and refrigerators.<br>Cell Biology Sample Prep Lab Recommended | 3.0 (9'-6") |

| Space Name | $M^2$ (SF) per Person | Equipment/Furniture and Requirements | Hgt. m (ft) |
|---|---|---|---|
| Robotics | Equipment determines the size of the space. | Equipment.: robotic equipment PCR thermocycler can be placed on a bench top, other relatively small pieces of equipment refrigerators or freezers, and sequencers and/or synthesizers with local exhaust ventilation, etc. | 3.0 (9'-6") |

** Equipment determines the height

## G.4 Laboratory Support

Laboratory support space should be on the same planning module as the laboratory. It should provide for activities that are not housed directly in the laboratory but are critical to the efficient operation of a laboratory. This space is often shared by multiple laboratories and includes areas such as autoclave rooms, environmental rooms, computer rooms, darkrooms, developing rooms, equipment areas, glass wash, bench support, radioactive work areas, ice rooms and storage. Consideration should be given to locating noise, heat and vibration producing equipment in laboratory support spaces.

Autoclave/Sterilizer Room: An autoclave is an industrial appliance that uses pressurized steam to sterilize laboratory instruments, glassware, other hard materials, and to decontaminate infectious waste. When an ethylene oxide (ETO) sterilizer is required, the NIH Division of Occupation Health and Safety must test and approve it. ETO sterilizers must be ventilated according to EPA standards and manufacturer guidelines must be followed for installation. The autoclave area requires overhead exhaust, floor drains, power, hot/cold water, steam, sink and condensate return lines, heating, ventilation, and air conditioning (HVAC), and drain, waste, and vent (DWV). Autoclaves come in a variety of sizes and models including those that have pass through capability. The size and type of the autoclave should be determined by the specific function for the area and by the anticipated frequency of use. If natural gas is provided, the environmental room should be supplied with supply and exhaust ventilation. See Chapter 6. HVAC. Decontamination autoclaves should have adjacent waste storage space. Glassware autoclaves should have associated marshalling and glassware storage areas nearby. All finishes must be moisture resistant. Doors to the room must accommodate large equipment sizes.

Glass Wash: The glass wash area should provide space for either an industrial sized unit or an under counter glass wash unit depending on the needs of the facility. Glass wash areas may be centralized to serve an entire building or floor. However, since so much laboratory ware is now disposable, there is less need for large glass wash facilities. Many labs are purchasing under the counter glass washers that can run small loads and do not require support staff to operate them. Storage for detergents must be provided.

Glass wash areas may be combined with autoclave functions because similar utilities are required. Marshalling areas for clean and dirty glassware, drying appliances and carts are required. Counters should be stainless steel and on legs. A large sink and overhead exhaust are required.

All areas in a centralized glass washroom should be thoroughly caulked and sealed, and have a fixed ceiling, non-slip epoxy floors, and cleanable walls to withstand moisture and prevent pest infestation. Masonry or metal stud construction is appropriate. Epoxy coated walls are required. Space must be provided for staging clean and dirty glassware. Utilities include HVAC with supplemental cooling, electricity, cold water, reverse osmosis, DWV, vacuum, telecommunications, and equipment alarm systems.

Controlled Environment Rooms: Controlled environment rooms are used for long-term experiments that are temperature controlled (warm or cold), or humidity sensitive and often require instrument set ups that are not easily moved.

A cold room is an environmentally controlled prefabricated unit usually operated at 4$^{O}$C. A warm room is an environmentally controlled prefabricated unit often used for growing cell cultures, usually at 37$^{O}$C at a constant temperature and humidity. Controlled environment rooms are available with variable temperature ranges and can be adjusted for use either as a cold or warm room. The prefabricated unit may require that the floor be a depressed slab or a ramp may be required to access the room.

Controlled environment rooms should have stainless steel counters on legs, wire shelves, and a stainless steel sink. Utilities include power, vacuum, and mechanical ventilation, filtered water, and fire alarm strobe light. Natural gas may be required based on program needs. If natural gas is provided, the environmental room must be supplied with supply and exhaust ventilation. Requirements for compressed air, gas and vacuum shall be verified during programming. A sink is sometimes required. Temperature controlled rooms shall be lockable, and all mechanical components shall be accessible and serviceable from outside the room. A high and low temperature monitoring and alarm system shall be connected to a central equipment alarm system. All gaps between the room and adjacent construction shall be sealed. Provide emergency exhaust capability. A manual door release must be provided inside the environmental room.

Computer Mainframe Area: This area supports computer mainframes or processors. Access flooring may be required. HVAC, electricity, special power, emergency power, uninterruptible power, specialized grounding and telecommunications/LAN systems will be required. Supplemental cooling may also be required.

Darkroom (working or developing): The darkroom may house an automatic film processor or developing tanks, sink, film bin, and light-tight loading bench, countertop, safe light, and wall mounted film illuminators. This area should have casework, counters, worktables, and a sink. All doors, walls, ceilings, and penetrations shall be light tight. Darkrooms shall have a filtered light that can be used when film is exposed. Utilities include HVAC, electricity, hot/cold and chilled water, DWV, spot exhaust, telecommunications, and RO water. Requirements for compressed air, gas, and vacuum should be verified during programming. An electrolytic or cartridge silver recovery system shall be provided in darkrooms with automated processors. The dark room should be equipped or designed to prevent flooding of room adjacent and below the space and shall include the means for detecting flooding. If a flood alarm is specified, it must be both local and central. Darkroom-in-use indicators (an illuminated "In Use" sign) shall be provided outside this space. When the safe light is on, the "in use" light shall also switch on. If a revolving door is specified as the primary entry, "pop-out" capability should be provided, for accessibility and moving large equipment

Freestanding Equipment Areas: Freestanding equipment areas will provide space for shared equipment that may have high heat loads and high noise levels, such as large freezers (-70$^{O}$ C) and refrigerators, ultra centrifuges and cell sorters. Utilities include HVAC with supplemental cooling, electric, cold water, DWV, vacuum, telecommunications, and equipment alarm systems.

Bench Lab Support: High bench lab support rooms provide space for common use or specialized equipment such as DNA sequencers and synthesizers, spectrophotometers, isotope counters, and other robotic analyzers. Low bench lab support rooms provide shared space for microscopes, computer terminals, common desk space or tall instruments. Both high bench and low bench rooms, or shared rooms with a combination of both types of bench space will have a sink, eyewash, and emergency shower in accordance with DOHS requirements. In addition to the standard provision of utilities, compressed air, gas, spot exhaust, nitrogen, RO water, and telecommunications/LAN may be required.

Radioactive Work Area: This area provides space for isolated radiation work. It will have access to a chemical fume hood and an emergency shower. It shall have a sink, eyewash, and flammable solvent storage cabinet. Space may be provided for storage of wet and dry radioactive waste containers of different types. Utilities needed include HVAC, power, vacuum, compressed air, gas, hot/cold water, DWV, nitrogen, telecommunications, and RO water. Proper shielding shall be provided based on the type of isotope(s) to be used in the laboratory.

Standard Ice Support Room: In addition to housing ice machines and dry ice boxes, these storage areas may also house liquid nitrogen freezers and liquid nitrogen cylinders. This room should be located near a freight elevator and be provided with HVAC, supplemental cooling, power, floor drain, and cold water.

General Storage Room: This room has shelving or lockable storage cubicles with "wire-bar"-type, easily cleanable shelving. Special utilities are not required.

Instrument Repair: Space should be provided for a customized instrument fabrication and repair shop. The space should include counter tops or work surfaces to fabricate and repair small customized laboratory instruments or devices. Limited floor space should also be provided to fabricate repair larger instruments. Adequate space for tools and materials should be provided.

## Summary Space Schedule for Laboratory Support

* Equipment determines the height of the space.

| Space Name | $M^2$ (SF) per Person | Equipment/Furniture and Requirements | Hgt. m (ft) |
|---|---|---|---|
| Autoclave/Sterilizer Room | Equipment determines the size of the space. | Autoclave or sterilizer with canopy exhaust and floor drain. | 3.0 (9'-6") |
| Glass Wash | Equipment determines the size of the space | Glassware washers, glassware dryers, sterilizer or autoclave stainless steel counters w/ double bowl sink, tall cabinets, and over head exhaust. | 3.0 (9'-6") |
| Controlled Environmental Rooms | Equipment determines the size of the space. | Prefabricated unit, stainless steel wire shelves, stainless steel counter top, uni-strut support. Do not use metal casework other than stainless steel. | * |
| Computer Terminal Area | | Work Surfaces for PCs pedestal to store personal items | 3.0 (9'-6") |
| Computer Mainframe Area | Equipment determines the size of the space | Main frame or micro processor, file server, LAN equipment, monitors, etc. | 3.0 (9'-6") |
| Darkroom | Equipment determines the size of the space | Photo development equipment, plastic laminate counters, shelves, roll film dryer, enlarging station, refrigerator and film processing sink w/ chiller. | 3.0 (9'-6") |

| Space Name | $M^2$ (SF) per Person | Equipment/Furniture and Requirements | Hgt. m (ft) |
|---|---|---|---|
| Free Standing Equipment area | Equipment determines the size of the space | Freezers, centrifuges and other noise and heat generating equipment, casework w/ epoxy counter tops and sink. | 3.0 (9'-6") |
| Bench Lab Support Rooms | 9.3 | Sink w/eyewash and high benches or low benches. | 3.0 (9'-6") |
| Radioactive Work Area | 16.5 | Fume hood, sink w/eyewash, emergency shower flammable storage cabinets and casework. | 3.0 (9'-6") |
| Standard Ice Support | Equipment determines the size of the space | Liquid nitrogen freezer, liquid nitrogen cylinders, wet ice machine, and dry ice box. | 3.0 (9'-6") |
| General Laboratory Storage | As required | | 3.0 (9'-6") |
| Instrument Repair | 11.25 | Countertops, chairs, stools, shelves, storage bins. | 3.0 (9'-6") |

## G.5 Administrative, Interaction and Ancillary Space

Offices: Offices should be positioned to achieve close proximity to the occupant's laboratory workspace. Finish with anti microbial finishes. Laboratory chiefs, section chiefs, principal investigators, and senior scientists should be provided with private offices wherever possible. If feasible, offices should be provided with natural light. Semiprivate offices may be provided for postdoctoral fellows. Open office space should be provided for clerical personnel. Sound damping and sound insulation should be considered. Desk and storage space for laboratory technicians are usually in open areas adjacent to lab benches and should include provisions for privacy. Consideration may be given to clustering offices in order to have potential for sharing support staff. Storage requirements must be considered for records/files, copiers, and mail areas. Ergonomic furniture should be used in the office. An area to hang coats should be provided. Office and file rooms should be lockable. Space for paper recycling containers and/or shredders should be provided

The facility should have a central reception area located as close to the main facility entrance as possible, where guests and vendors can be met and directed appropriately. The area should have a space for furniture for visitor waiting. A phone line should be provided. Intercom or paging systems should be provided if required by the program.

Lockers: Personal space within the context of an open laboratory is much less private and secure than in conventional, enclosed laboratory space. Although there is the option of installing locks on casework doors and drawers, there is an immediate need to provide space for employees to store personal belongings including food and coats, outside of the laboratory. Lockers may be built-in and located in the corridors or in the break rooms. Lockers may also be located in a separate room.

Conference Rooms: Small conference rooms for 8-10 people shall be provided for formal and informal meetings of section staffs. Large conference rooms for up to 25 people will be provided for meetings of the laboratory staff. All conference facilities will be shared. Each space should be equipped with white boards, outlets to accommodate audiovisual and projection equipment (laptop, slides and overhead projectors), light dimming, and blackout control, as well as telecommunications/LAN capabilities. Conference rooms should be equipped to accommodate flexible seating arrangements, secure/lockable storage closets, space for waste and recycling containers, and accessibility to permit ease of cleaning and servicing. The need and size of conference rooms over 49 persons shall be determined during programming per NIH Events Management requirements.

Break Rooms: These areas permit the safe consumption of food and beverages outside the laboratory while creating an inviting area for interaction. These areas serve as lounges and small informal meeting spaces for the employees. Acoustical separation of these areas from surrounding spaces is required. All break rooms should be equipped with a white board, tack board, table and chairs. Some larger break rooms may also require a bookcase, cabinets, sink and counter tops, microwave oven, and refrigerator. Lockable storage within a break room is desirable. All break rooms should include space for waste and recycling containers. These containers shall be adequately sized to support the occupancy of the space and be constructed of durable cleanable materials. They shall be accessible to permit ease of cleaning and servicing. Furnishings used in a break room must be cleanable and promote good sanitation. A library or resource center could be combined with a conference or break room or be a separate entity. Provide a break area on each floor, or for each laboratory neighborhood. These spaces must be provided with exhaust ventilation to prevent migration of cooking odors. Sufficient electrical receptacles should be provided for food and beverage preparation.

Lactation Rooms: In support of the NIH Work and Family Initiative, lactation rooms should be provided with two cubicle(s) each in compliance with the following requirements:

A minimum of 2.8 $m^2$ (30 nsf) shall be provided for each lactation cubicle. Six private cubicles for every 1000 people shall be the general metric, with a minimum provision of one cubicle for populations under 100. Lactation rooms should be scattered throughout the building and shall include:

- A built in laminate or solid surface counter, approximately 1.5 m ( 5-0")wide x 737 mm (2'-6") high x 610 mm (2'-0") deep for each cubicle
- A cubicle curtain or door to provide privacy for each cubicle if there is more than one in the lactation room.
- Lockable door or door with key code access at the entry to the room (not to each cubicle)
- Relaxing, quiet environment, with non glaring lighting.
- One duplex electrical outlet at counter height in each cubicle.
- One sink within the lactation room. If the lactation room can be entered from women's restroom, the sinks in the restroom can be used instead.
- A wall phone near the door.

Shower and Changing Areas: Personnel showers with changing areas should be provided for each sex. In renovations where this may not be possible, consider providing a unisex shower for employees. Shower and changing areas are typically adjacent to or co-located with restrooms. Include lockers and changing benches, clothes hooks and an electrical outlet adjacent to mirror and shelf. Shower and changing areas shall be accessible to individuals with disabilities. Refer to local plumbing code to determine the number showers required based on building population.

Cyber Café: This specialty area is a response to the age of computer communication, rapid information retrieval and multitasking. A cyber café is a multipurpose space containing computer hookups for laptops at desks or tables, a refreshment bar, and informal meeting space. These areas foster interaction among building occupants and draw in others from outside the building.

Library/Reading Room: Libraries are no longer as popular or as necessary as they once were with the advent of online journals. However, there still may be a desire for a reading room where current hard copy journals are kept. The library room should be a quiet, comfortable, well lit space with adequate perimeter shelving for books and journals. It should have electrical and data receptacles for all research desks provided.

## Summary Space Schedule for Administrative, Interaction and Ancillary Space

| Space Name | M² (SF) per Person | Equipment/Furniture and Requirements | Hgt. m (ft) |
|---|---|---|---|
| Laboratory Chief's Office | 15.0 (160) | Work surfaces w/binder bins, convergent work surfaces, lateral files, tack boards and white boards. | 2.4 (8'-0") |
| Section Chief's Office | 12.0 (130) | Work surfaces w/binder bins, convergent work surfaces, lateral files, tack boards and white boards. | 2.4 (8'-0") |
| Principal Investigator's Office | 12.0 (130) | Work surfaces w/binder bins, convergent work surfaces, lateral files, tack boards and white boards. | 2.4 (8'-0") |
| Senior Permanent (Tenured) Scientist Office | 12.0 (130) | Work surfaces w/binder bins, convergent work surfaces, lateral files, tack boards and white boards. | 2.4 (8'-0") |
| Post Doctoral Fellow's Workstation | 10.0 (108) | Work surfaces w/binder bins and lateral files. | 2.4 (8'-0") |
| Receptionist or Chief's Secretary Workstation | 8.0 (86) | Counter, work surfaces w/binder bins and lateral files. | 2.4 (8'-0") |
| Clerical Workstation | 8.0 (86) | Work surfaces w/binder bins and lateral files. | 2.4 (8'-0") |
| Building Engineer's Office | 12.0 (130) | Work surfaces w/binder bins and lateral files. | 2.4 (8'-0") |
| Logistics Office | 12.0 (130) | Work surfaces w/binder bins and lateral files. | 2.4 (8'-0") |
| Lockers | 0.3 (3) | Lockers and benches. | 2.4 (8'-0") |
| Conference Room | 1.86 (20) | Conference table, chairs A/V equipment, white boards, etc. | 2 400+ |
| Break Areas | | Vending machines, counters, tables' w/chairs under the counter refrigerator, recycle bins, and microwave oven with canopy exhaust hood. | 2.4 (8'-0") |
| Lactation Room | 10.0 (108) | Lounge chair, table, counter top, under counter refrigerator, and shelves. | 2.4 (8'-0") |
| Shower and Changing Room | Fixtures and equipment determines the space | Lockers and benches. In addition to the area required for plumbing fixtures the area for lockers and benches is 0.3 per person. | 2.4 (8'-0") |

## G.6 Building Operational Areas

Building operational areas consist of non-programmatic space that is not necessarily associated with the scientific activities of the laboratory. However, these spaces or areas are required for a functional and well designed laboratory. Building operational areas include circulation, toilets, shipping and receiving areas, mechanical and electrical rooms, telecommunications, hazardous waste holding room, and utility distribution areas that strongly influence the design of the laboratory.

Entrance Lobbies: The lobby can be characterized as the introduction to the building or a place where one is assisted in way finding. The lobby can be an interaction space with seating, bulletin boards and directories. A security station is desirable in the lobby. Lobbies should be provided with vestibules to enhance energy conservation. Vestibules should include features to minimize dirt, moisture, etc. from being track into the facility.

Housekeeping Closets: All buildings must be equipped with appropriately sized housekeeping closets located throughout the facility to adequately serve its needs. A housekeeping closet must be provided with both supply air and exhaust to reduce humidity and control odors. Closets should be fitted with wire bar shelving, mop and broom hangers, a floor sink, GFI receptacle and adequate lighting. Closets should be sized to hold cleaning supplies and equipment only. Storage of personal items, chairs, cabinets, etc. creates clutter and promotes pest activity. The interior of the closet must be finished with materials and surfaces that are cleanable, moisture resistant and durable. Backflow prevention is mandatory on hose bibs.

## G.7 Materials Management

For laboratory facilities, the issue of materials management concerns the storage of laboratory materials and supplies and the handling, storage and disposal of chemical and biohazardous waste. Material handling zones should be designed adjacent to dedicated service elevators for purposes of staging, dispensing and disposal of laboratory materials and supplies. Within each building zone, separate areas for chemical and hazardous waste storage must be provided that meet OSHA standards, codes and other appropriate regulations.

Shipping and Receiving Area: Space should be provided for shipping and receiving adjacent to a loading dock. The receiving area should provide adequate space for the storage and staging of material. A small office should be provided for personnel who will be responsible for tracking the distribution of material. The loading dock should be covered and provided with dock height adjusters. In a multistory facility, consideration should be given to

material handling zones and storage at each floor. Separate and dedicated space shall be provided for animal receiving and carcass disposal if the building has animal facilities.

Loading Docks: The loading dock shall have adequate space and lighting for proper marshalling, inspection, and cleaning of materials received and shipped from the building. Solid waste is often containerized at the loading dock but solid waste containers shall not be stationed directly in front of overhead doors.

Based on the amount and duration of activity, the loading dock may be a point of pest ingress for the following reasons:

- Doors often remain open for extended periods of time.
- Solid waste and recyclables, which are attractive to pests, are containerized and stored at the dock.
- Outside air can be pulled into negative buildings along with pests.
- Proper cleaning and sanitation are often difficult to achieve.
- Selection of loading dock outdoor lights must be approved by Community Health Branch, DOHS.

Because of heavy industrial use of this area, maintenance issues can contribute to pest problems. Therefore, the loading dock shall be provided with a buffer between the exterior and the interior of the building. Screens, specialty doors, plastic strip doors, and electric insect light traps shall be used to create a positive barrier to pests. Overhead doors shall be fitted with proper sweeps, gaskets, and brushes to exclude pests around the perimeter of the entire door. Air curtains and other similar devices shall be used to exclude pests and to create a dust and dirt barrier when the doors are opened. "Clean" deliveries and deliveries of food shall not be commingled with waste and "dirty" areas of the dock.

The A/E shall use the following loading dock areas planning list as a means of providing the types of spaces required:

- Dock manager.
- Dumpsters/Compactors.
- Cryogenics.
- Generators.
- Guard stations.
- MPW cold box.
- Office control.
- Oil separator pits.
- Radiological waste room.
- Chemical waste marshalling area.

- Recycling containers (cardboard compactor).
- Secondary entry.
- Security elements.
- Tank farm for cylinders.
- Washroom for drivers.
- Dock materials handling devices (dock levelers, cranes, forklifts, recharging stations, etc.

Chemical waste rooms, biological waste rooms and radiological waste rooms shall be provided with card access control opening only. Sizes for these areas shall be based on certain throughput, but no less than the minimum sizes established by NIH. See Section 1-9 Environmental Management/Radiation Safety. The Project Officer shall check with DEP for Certificates of Compliance.

- Provide recycling room, preferably outside the loading dock.
- Provide MPW cold box (minimum 2440mm x 3050mm [8'-0"x10-0"]).
- Provide cardboard recycling containers bolted to the loading dock and cardboard compactor.
- Provide tank farms with restraint brackets, if required at each loading dock with appropriate set backs from the building.
- Provide a wall mounted ABC type fire extinguisher.
- Provide a safety shower and eye wash station with no floor drain.
- Provide one duplex electrical outlet on each wall of the room. All electrical appurtenances in the room shall comply with local requirements.
- Provide standard lighting.
- Provide a wall mounted telephone either in the room or immediately outside for emergency communications.
- Provide ramp to access loading dock.
- Provide unisex toilet.
- Provide area for storage of wooden palettes.
- Provide quick opening rolling steel doors at loading dock. All rolling doors shall be provided with the housing on the inside of the loading dock. Nylon bristle sweeps required at sill and jambs. If air curtain is installed, it shall be flush mounted and extend 50mm on each side of opening.
- Provide epoxy coating finish for the entire area.

Biomedical Laboratory Loading Docks: Provide space in the area of the loading dock for the collection and storage of medical pathological waste (MPW), chemical waste, and radiological waste. A cold box capable of holding a minimum of 30 MPW boxes overnight shall

be supplied in close proximity to the loading dock. See Section 1-9 Environmental Management/Radiation Safety.

MPW Waste Collection Stations: Space must also be provided for MPW collection stations on each floor of laboratory buildings, and as directed by DEP.

Materials Handling: Movement of materials and laboratory research animals from loading dock facilities to multiple points of use must be carefully considered and evaluated in development of the overall building circulation system. Materials movement from loading dock to various points of use should be provided in separate corridors to dedicated service elevators. Once in the laboratory research areas, materials movement will be in common public corridors with limited and controlled movement. Material handling zones should be designed adjacent to dedicated service elevators for purposes of staging, dispensing and disposing of laboratory materials, supplies and equipment.

Movement of Laboratory Animals: Movement of laboratory animals will be restricted to within the confines of the animal facility. Researchers requiring immediate access to their animal populations for assessment studies and other specialized programs should be provided laboratories adjacent to the facility with controlled access through limited points of entry.

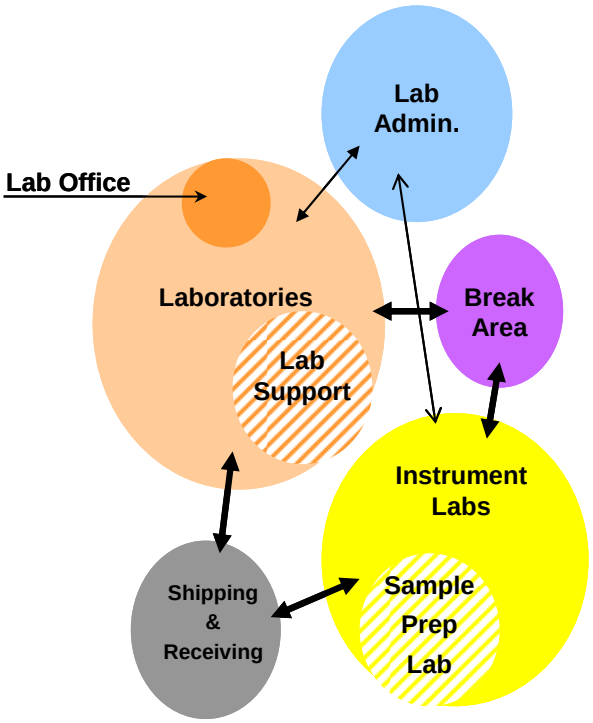
## H. Functional Relationships and Laboratory Planning Concepts

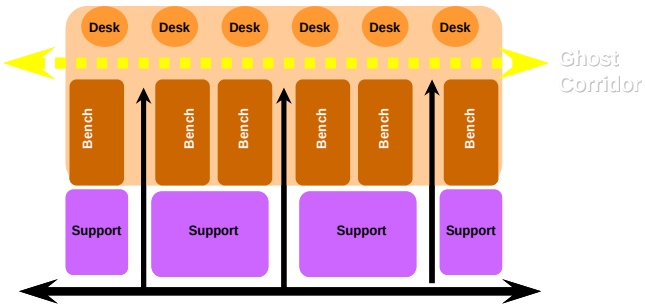
In planning a laboratory, the designer must address the relationships of all related functions or activities. By combining similar types of functions in zones, the building becomes more efficient. The following should be used as a guide to determine space and functional relationships when planning a laboratory.

- Define the organizational structure or the general functional philosophy of the proposed occupants.
- Define the levels of interaction required by the functional philosophy.
- Diagram the proposed interactions to determine their efficacy.
- Determine waste and material handling movement requirements for the individual work zones.
- Identify safety health hazard containment, and animal care if applicable issues that must be addressed in planning.
- Determine specific laboratory support adjacency requirements for each laboratory zone.
- Define office adjacencies to laboratory work space.
- Determine which laboratory spaces will need isolated work zones that may require special mechanical services.

In addition to determining the types and degree of adjacencies, it is essential to obtain the following information when planning flexible and adaptable workspaces.

- Mechanical electrical and plumbing utility requirements
- Directional airflow requirements
- Fire protection requirements
- Biohazard and radiation safety requirements
- Chemicals used
- Major scientific equipment to be installed including environmental rooms
- Density of fume hoods
- Building population
- Number of work stations
- Types of nonstandard work stations such as electro physiology rigs
- Special requirements such as vibration and noise control and shielding



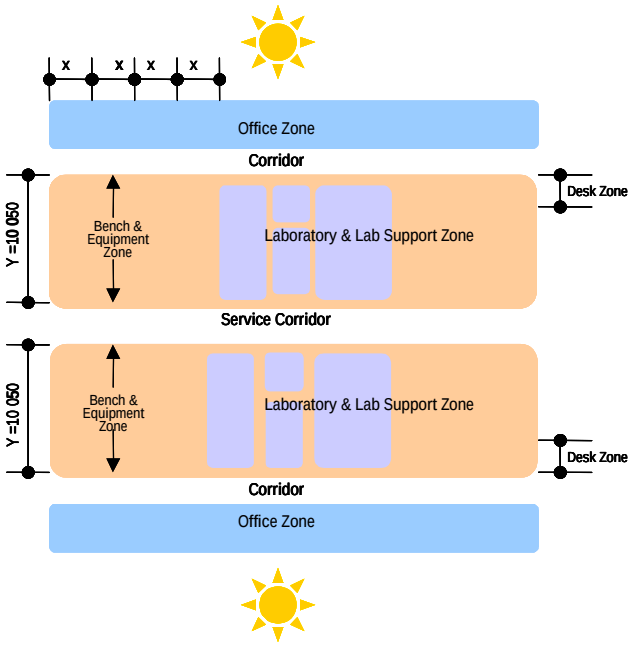



# Laboratory Functional Relationship Diagrams

## H.1 Planning Diagrams

The planning diagrams describe in graphic form the basic planning zones for the modular development and relationships between laboratory zones, office zones, desk zones, corridors, and support zones. These are diagrammatic only and must be adapted to requirements of the specific building's program of requirements, site constraints, and user requirements.

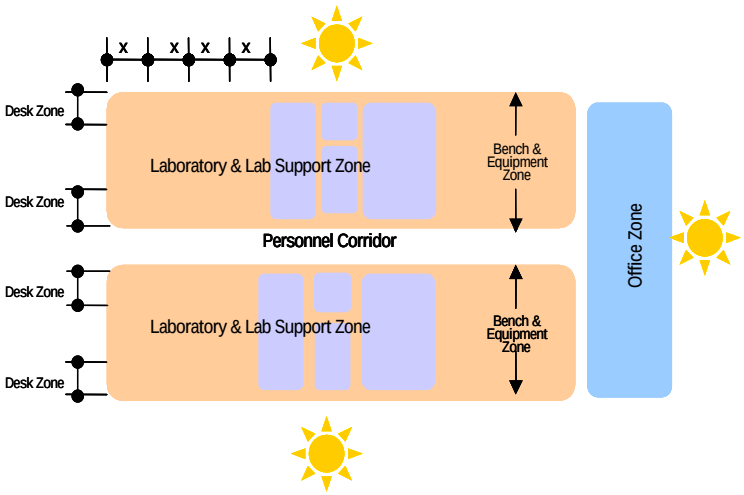
Laboratory and Laboratory Support Concept: The planning of a laboratory building must address both relationships of functions and circulation. This diagram illustrates primary personnel circulation between the lab and lab support zone and the office zone. The central service corridor supports the laboratories and segregates the flow of people and materials.




Laboratory Module with Service Corridor: The layout of the laboratory should provide adequate space and a safe working environment. Desks are located near the personnel corridor while utilities are near the service corridor. Direct natural light is generally not available.

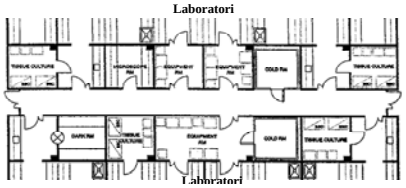
Laboratory Zones with Single Corridor: This diagram illustrates a primary personnel corridor between the lab zones connecting to a central office zone. This central corridor supports the laboratories and the offices combining the flow of people and materials. All spaces receive direct natural light.

Laboratory and Laboratory Support Zones with Single Corridor: A double-loaded personnel corridor with a lab zone on one side and an office zone on the other side. This central corridor supports the laboratories and the offices, combining the flow of



people and materials. All spaces receive natural light.

Laboratory Module with Single Corridor: Desks are located either near the entry to the corridor or at the end of the lab near the window. Equipment of lab components may be arranged in a variety of ways within the lab. Utilities distribution, people, and materials flow are combined in a single corridor. Direct natural light is available to the laboratory.



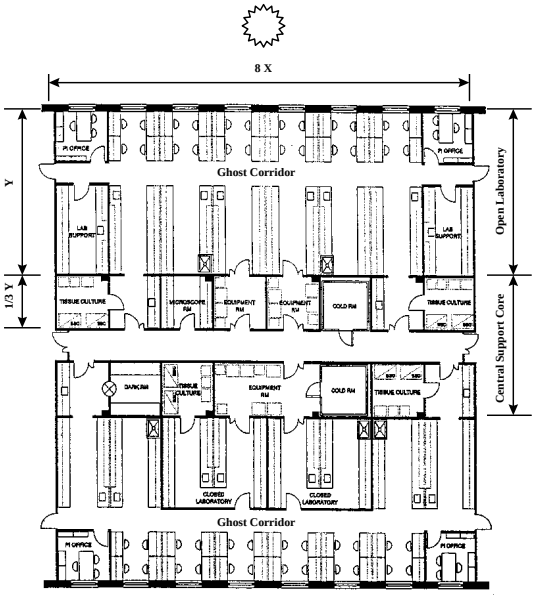
Lab Support Core

## H.2 Laboratory Planning Concepts

Lab Support Core Concept: All laboratory support functions are centrally located and accessible from both sides in the lab support core concept. This concept is very functional and efficient. It has a grossing factor that can range from 1.67 to 1.82. Material and service traffic can be segregated from personnel traffic. The lab support core concept is well suited for research that is instrument intensive.

Open Laboratories Concept: These are laboratories without partitions. The open laboratory concept encourages interaction between researchers. Depending on the buildings design, it can also enhance the laboratories relationship to the outside environment by placing primary research space to the exterior of the building. It provides a flexible environment that can be easily organized in a generic and modular pattern. Physical barriers between researchers should be minimized to provide a climate for open communications. Door used for directional air flow must be identified.

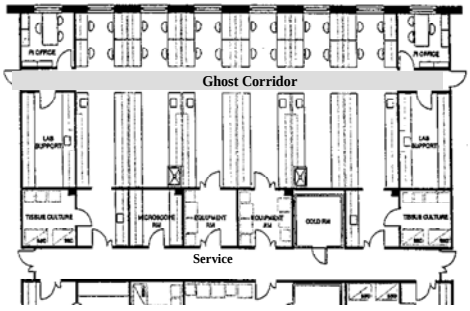

Open Laboratory Concept, Bldg. 37 J.P. (Fred) Khoshbin, R.A. NIH Architect



**Proposed Laboratory Neighborhood for Building 50**

Laboratory Neighborhood Concept:
An approach to planning the layout of a laboratory building that brings together in a single space all of the resources that the researcher uses on a daily basis. A laboratory neighborhood includes not just laboratories and lab support but also office and office support areas, supplies, and all shared equipment including computer equipment. Laboratory neighborhoods are expected to promote greater productivity, eliminate the need to dupli-

cate expensive laboratory support space, and promote a sense of scientific community. boratory neighborhoods bring together 30 - 60 people, including perhaps 6 - 8 principal investigators, plus their post doctoral fellows and lab assistants, and various support functions. Laboratory neighborhoods should be clearly organized for ease of movement. Typically, laboratories are on the outside, with support space inside. Numerous cross corridors or cross lab rooms make it easy to move about in the neighborhood. Doors used for directional airflow must be identified.



Ghost Corridor

Ghost Corridors: "Ghost corridors" are aisles that connect laboratories and improve communications in a laboratory neighborhood. In some recently constructed laboratories, ghost corridors run through one side of the laboratory. Ghost corridors provide secondary emergency exits for the laboratories; however, they are not the primary fire or emergency exits. This preserves the secondary exit from the lab but allows separation of labs with incompatible functions. Ghost corridors allow people, equipment and samples to move easily between labs. Lab suites of three to four labs (which might be used by one group working under a principal investigator) can be easily grouped together.

## 2-3-30 Design Document Requirements

### A. Program of Requirements

Project Officers are encouraged to use the information in this Section to prepare PORs for NIH laboratory facilities. A POR for the specific project shall be developed in accordance with Volume I Section 2-5 of the HHS Facilities Program Manual. In addition the programming process shall address user needs, population density, building circulation, mechanical, electrical, and plumbing systems, and all aspects of safety.

### B. NIH Facility Budget Estimates

NIH Planners and Project Officers are encouraged to use the information in this section to prepare budget estimates for NIH laboratories.

### C. HHS Facility Project Approval Agreements

Project Officers are encouraged to use the information in this Section to prepare FPAAs for NIH laboratory facilities.

### D. Project Definition Rating Index

Project Officers are encouraged to use the information in this Section to enhance their PDRI scores.

## E. Laboratory Concept Design

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this Section as a reference in developing their conceptual design.

## E.1 Outline Specifications

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this Section as a reference in developing their outline specifications for their NIH laboratory project.

## E.2 Square Meter or Broad Order of Magnitude Cost Estimate

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this Section as a reference in developing their broad order of magnitude cost estimate.

# Section 2-4: Animal Research Facilities



## 2-4-00 Design Requirements

The purpose of this section is to develop NIH Programs of Requirements (POR) and other planning and programming documents and shall not be used for design review. Concept or schematic designs shall be reviewed against the POR.

Space utilization of NIH animal research facilities shall be in accordance with Paragraph 2-2-20.B in Volume II of the HHS Facilities Program Manual.

- Excellence in design with commitment to quality by the design and management team is a primary goal for all NIH.
- Designs for new animal research facilities shall include considerations for future expansion including horizontal and vertical expansion. Building massing shall be consistent with the current master plan.
- Columns shall not fall within the animal research facility planning module so as to prevent interference with facility space planning and layouts and inefficient use of valuable space.
- Interstitial space shall be designed to scale. A model or full size mockup of the interstitial space is required.
- The laboratory planning module shall be considered the primary building module in multiuse facilities due to the importance of the laboratory planning module to functional and safety issues.

### A. Program Objectives

Program objectives must be determined as early in the planning process as possible. It is crucial to identify the variety of species that the facility should be expected to accommodate over time; the temperature and humidity range that each species can tolerate; and the degree of flexibility and adaptability required within the facility to accommodate different species. The designer shall determine the cost impact of making some or all areas of the facility more flexible than other areas. In order to provide for an environment within the animal research facility that meets the program objectives, the designer will collect data on spatial allocations, functional adjacencies, user requirements, staffing projections, flexibility re-

quirements, redundancy requirements, security requirements, architectural finishes, fixed equipment needs and circulation of personnel, materials, animals and waste.

## A.1 Planning Criteria:

The animal research facility will be designed to house animals in an appropriate species specific environment that meets or exceeds all applicable policies, guidelines and regulations as outlined in the Guide for the Care and Use of Laboratory Animals (Guide), PHS policy and animal welfare regulations. In addition, facilities must meet the minimum requirements to be accredited by the American Association for Accreditation of Laboratory Animal Care, (AAALAC). The ideal facility will:

- Meet projected holding and programmatic requirements, while providing for expansion and flexibility in space utilization;
- Provide for efficiency of management through innovation and flexible design;
- Be cost effective in design, construction, operation, maintenance;
- Utilize innovative design and construction to minimize future energy, maintenance, labor, and expansion costs; and
- Provide an ergonomic and user friendly work environment.
- Include redundancies.
- Have capacity for increased holding space.

## A.2 Space Requirements

The space requirements for animal facilities vary greatly. Requirements are dependent on the specific use of the facility, type and density of animals housed, type of caging and racking systems, number of investigators utilizing the facility, and operational methodologies of the facility. Each proposed facility shall require careful analysis by the A/E and consultation with users to determine adequate space requirements.

Criteria for animal housing space is set forth in the DRM. The space requirements for a facility shall consider the total animal population, number of species, isolation requirements, number of animals per room, and number of investigators and research projects anticipated. The assignment of support space is based on protocol, equipment, and process and can be determined only on the basis of an evaluation of the specific project program of the facility users. Application of these space criteria requires the A/E to analyze functional requirements in light of specific project needs.

## A.2 Specialized Design and Review by DOHS Community Health Branch (CHB)

Animal facilities present some of the most challenging circumstances to an effective pest management program and the performance of integrated pest management (IPM) services. Additional care and attention shall be paid during all phases of planning, design, and con-

struction of animal facilities. Some components that require specialized design and review by DOHS Community Health Branch (CHB) include:

- Building integrity (site design, building envelope, exterior building lighting).
- Receiving areas.
- Interior wall, floor, and ceiling finishes.
- Door types, locations, and materials.
- Wall and door protection design and materials.
- Access panels.
- Caulking and sealing locations and details.
- Interior lighting.
- Cage wash design.
- Solid waste disposal, recycling, and storage facilities.
- Floor drains.
- Locker rooms and break rooms.
- Administration areas.

These items shall be evaluated and reviewed with respect to the overall program requirements of the entire building, specific animal species, size of the facility, and anticipated future use(s) of the facility.

## 2-4-10 Design Guidance

This Section describes in general and specific terms the NIH requirements for the planning and design of facilities that house animals and related functions. Considerable animal research is conducted at the NIH in order to support NIH's mission to improve the health of the American people through biomedical research. The Guide for the Care and Use of Laboratory Animals (The Guide) published by National Academy Press covers all aspects of the care and use of laboratory animals, including institutional policies for monitoring animals and providing care. The Guide should serve as an aid to develop policies governing the care and use of animals based on the institution's particular requirements and in compliance with applicable federal, state and local laws and regulations.

In the U.S., research facilities requiring the use of animals must conform to The Guide to be accredited by the American Association for Accreditation of Laboratory Animal Care (AAALAC). For accreditation the environment within the facility must provide for the health, safety, comfort and well being of the animals and staff. Plans for building and renovations of animal facilities must be reviewed and approved by the Office of Animal Care and Use

(OACU). Animals are not allowed to be housed in laboratories or spaces other than approved animal housing facilities for longer than 24 hours unless the area is established as a satellite animal housing facility. Establishing a satellite animal housing facility may require short-term design modifications that facilitate monitoring the local environment OACU requirements.

## A. Animal Research Facility Trends

Biomedical research is heavily dependent on animal research to create animal models for the study of human disease processes. Fluctuations in the animal species of choice may vary from time to time and for this reason the facilities must be capable of meeting ever changing animal research requirements. The design of these facilities must be flexible and adaptable.

A great deal of animal research at NIH involves genetic mutations and manipulation (transgenic technology) of specific animal traits and testing these traits by performing behavioral studies, imaging studies, and biochemical studies. Toxicology studies are performed to observe the effects drugs have on developmental and metabolic processes and on behavior patterns.

Long term observation of animals may dictate design features for a specific species. Until recently rodents and nonhuman primates have been the primary research animals of choice. There has been a dramatic increase in the use of aquatic species (zebra fish, sea urchins and other marine species) resulting in the adaptation and renovation of older facilities and the potential need to accommodate aquatic species in new facilities. Large animals (primarily sheep and pigs) are used for cardiothoracic surgery and require pre and post operative holding space. Dogs, cats and chickens are used for specific types of research but are used in small numbers.

There is a trend to provide better and species specific “enrichment” for nonhuman primates and large animals. Enrichment requirements will impact on design of the facility if the program calls for play rooms, natural light, views of activity, group housing, animal runs, and storage of toys.

Other trends in animal research facilities include an increased use of robotic cage wash equipment to supplement staff shortages and reduce staff injuries; heightened security measures; more extensive and expensive environmental controls to protect unique animal colonies; and an increased need for support facilities within the animal research facility such as diagnostic labs, imaging equipment, conference rooms, special function and core suites.

Each of these trends demands special design considerations that must be addressed in the planning process.

## B. Animal Research Facility Activities

The activities performed in an animal research facility include, but are not limited to, providing routine animal and environmental maintenance, performing animal research and providing general administrative services. In addition, an animal research facility requires a significant amount of support space. Environmental maintenance includes bedding changes, food preparation, routine cage washing, room cleaning, local filter maintenance, pest management and waste disposal.

Routine animal maintenance includes daily animal examination, routine pathology to determine colony health status and animal breeding for colony maintenance. Animal research includes genetics studies, animal testing that requires the administration of drugs, chemicals, or biological agents, pathology, diagnostics, surgical procedures, imaging, phenotyping, behavioral studies and record keeping of a highly detailed nature. Animal research facility administration areas should provide space for a central reception area, veterinarian offices, office support staff areas, and technical and laboratory supervisory staff offices. Animal research support activities include animal shipping and receiving, decontamination of materials entering the facility, storage and dispensing of animal feed and bedding, cage washing, laundry services, cold storage of medical pathological waste, and animal caretaker requirements such as lockers and a lunch room.

## C. Design Goals and Objectives

The NIH will provide state-of-the-art animal research facilities to enhance and maintain its position as the world leader in biomedical research. The NIH will accomplish this goal by constructing new animal research facilities and renovating older ones to meet ever changing biomedical research requirements. These guidelines will be applied to new animal research facilities and, to the extent possible, to renovation projects. The following goals and objectives define the minimum recommended program requirements and recommendations for the design of animal research facilities.

### C.1 Quality of Life and Environmental Considerations

The immediate environment directly and indirectly affects an animal's biological and behavioral responses. Noise, light, vibration, sound, species thermal requirement ventilation, etc. of the animal's cage affect the quality of life and may adversely impact the research. At

a minimum, animal holding and procedure areas must be designed to ensure animal well being, to meet research requirements, able to be sanitized and easily maintainable, and to minimize experimental variables and maximize predictability.

## C.2 Animal Well Being

The facility should support a healthy social environment for the animals that mimics the animal's natural social environment. The characteristics of each species must be considered in deciding how to house a diverse animal species. There is very little data comparing the relationship of quality or quantity of an animal's activity to its physical or psychological well being. A cage does not necessarily limit the amount of animal activity although it may alter the form of activity the animal can pursue. The need for exercise or induced activity is subject to the judgment of the animal science professional based on an understanding of the species or breed, its temperament, age, history, physical condition, nature of the research, and expected duration of animal research facility residence. Examples of supplementary activity that can be provided include furnishing a treadmill or exercise wheel, walking on a leash, providing access to a run, or releasing an animal from its cage into an animal play room/activity area. Provisions shall be made for animals with specialized locomotion patterns to express these patterns, especially when animals are held for long periods. For example, ropes, bars, and perches are appropriate for brachiating nonhuman primates.

## C.3 Employee Well Being:

The animal research facility is also a workplace for employees. Therefore, the occupational health and safety of personnel must be considered. The environment shall be aesthetically pleasing to employees and consistent with the needs of investigators engaged in animal research. It should be efficient, secure, and easy to maintain and perform animal care taking services. Sufficient air supply, filtration, and exhaust shall be provided to minimize unpleasant animal odors and animal allergens. Provision of natural light, adequate work space, color, and ergonomic furniture systems are integral to a pleasing, functional, and effective work environment that will enhance productivity and aid in the recruitment and retention of quality personnel. In order to provide for an environment within the animal research facility that meets these goals, refer to animal facility space descriptions for information that impacts the quality of life of the animals and their caretakers.

## C.4 Graphics/Signage:

Without views to the outside or significant landmarks within the facility, orientation becomes a planning issue in an animal facility. It is recommended that a map of the corridor system be provided at strategic junctures in the hallway. Alternative way finding elements might be used such as directional markers on the walls, color coded corridors or artistic symbols de-

signating room or corridor use. Each room shall have a room number clearly displayed at its entry.

## C.5 Other Amenities:

Amenities such as lounges, break areas, training rooms, staff offices, and conference rooms should be provided. Placement and size of these rooms should be carefully thought out in order to maintain the integrity of the degree of facility contamination control that is defined in the program. Locker and shower facilities should be provided outside of the animal barrier area for staff whose work does not involve animal contact.

## C.6 Natural Light:

Natural light is not recommended in areas that will house animals that require regulated lighting cycles. These include but are not limited to rodents, rabbits, and fish. Windows may be desired in areas that house large animals such as nonhuman primates, dogs, or farm animals. With the exception of facilities housing larger farm species, most animal rooms should be equipped with artificial lighting systems that control the diurnal lighting cycle. Through the use of innovative design and construction, diurnal variation can be maintained. If windows or door vision panels are to be placed in animal rooms, veterinarians shall be consulted for placement of windows and window treatments.

The negative aspects of windows in animal facilities frequently dominate design, and opportunities can be missed to enhance the personal work environment with natural lighting. Windows should be provided in personnel and administrative areas.

## C.7 Lighting and Controls:

Fluorescent lighting is recommended in an animal facility. However, discussions shall be held with the veterinarian and researchers regarding the light spectrum and light covers of fluorescent lamps. Light covers should diffuse and soften the light so as to have a minimal effect on animals that may have higher than normal light sensitivity. Lighting should be suitable to the space and cleaning methods in the room, recessed, ceiling mounted and sealed and caulked to prevent vermin infestation.

Lighting control is a major consideration particularly in small animal holding rooms. Lighting control is typically required for large animal holding or procedure rooms as well. Light intensity can have an impact on research results under certain circumstances and may differ by species. Whenever possible, lighting should be centrally controlled, on emergency power and monitored at the room level. Monitoring of the lighting control system should be independent from the method used to control the lights. Consideration should be given to direct measurement of room illumination or monitoring the electrical circuit feeding the room light.

The ideal system would provide a local warning light alarm and, if required, remote audible alarms signaling lighting failures. Light monitoring control systems shall also be capable of providing reports for status and alarm conditions. Although it may be possible to group several rooms on a single timer, this should be discussed with the users. Animal protocols often call for diurnal lighting cycles (circadian rhythm) to be reversed or altered in length for the researchers needs or for the desired results of the experiment. These studies require lighting controls and automatic timers in all holding rooms and isolation cubicles. "Red light" or other lighting options within holding rooms, as determined by users, should be considered so researchers can enter a room during the dark cycle without affecting the animals.

## C.8 Noise:

Acoustical control is an important planning consideration and shall be evaluated during design. By examining adjacencies, the effects of noise can be addressed in the design layout. Most animals are stimulated and may be stressed by noise. Different species of animals will have different tolerances for high or low frequency noises. Certain frequencies can have an adverse affect on sensitive animals. These issues must be discussed with facility users.

Power ventilated racks generate noise. The rack density in a room will affect the noise level. Mechanical equipment may generate noise frequencies that are not noticeable to humans but will potentially affect animals housed near the source of the noise. This is further exacerbated by the requirement of hard, easily cleaned surfaces throughout. Most animals are stressed by noise, except for large animals not involved in behavioral testing. Equipment that generates noise should be remote or acoustically isolated from animal holding rooms wherever possible.

Large animals tend to be noisier than small animals although avian species (birds) are noisier in relation to their size than rodents. Animal species that generate noise should be isolated from those that are noise sensitive by either distance or sufficient acoustical isolation. Noise conductivity through the duct system should be taken into consideration.

Although rodents can adjust to constant low level background noise, background noise should be minimized or removed through the use of innovative design.

In all situations, it is imperative to eliminate the effects of sudden and variable noise producing elements, such as fire alarms, throughout the animal holding environments.

## C.9 Vibration Stability:

Vibration stability is important to maintaining a constant experimental environment for sensitive animals such as rodents. Therefore, rodent holding and test rooms should be located

away from areas such as a cage wash, major circulation corridors where racks are frequently in transit, mechanical rooms and elevator shafts. Vibration is not as much of an issue for large animals except in behavior testing rooms. Vibration studies should be performed to determine how best to achieve the maximum allowable vibration levels as determined by instruments and animals to be used in the area. See Chapter 5 Structural

Vibration stability is required in an animal facility where specialized equipment will be used such as animal imaging equipment, electron microscopy, and electrophysiology procedures including intracellular data collection equipment. Vibration stability will be of greater concern if the animal facility is located in an upper level of a building rather than at ground level because of structural considerations. Sensitive pieces of equipment may require an isolation slab. Some equipment can be stabilized using a dampening device.

## D. Animal Research Facility Planning Parameters

### D.1 Ratio of Holding Rooms to Procedure Rooms:

During the programming stage the users should be consulted on whether animal holding rooms house multiple species and whether animal holding rooms and procedure rooms should be designed to be interchangeable with minimal structural modification. Flexibility in design of these critical areas provides for rapid accommodation of future programmatic changes and efficient space utilization.

As a general rule of thumb, one procedure room for every three to four small animal holding rooms should be considered. Clusters of isolation cubicles should have at least one procedure room per cluster. Suites should have a minimum of one procedure room within the suite. The ratio of procedure rooms to holding rooms for large animals shall be determined by scientific requirements and the specific program requirements of the facility. Most large animal holding facilities will require an extensive surgical suite with its accompanying specialty procedure and prep rooms. Terminal procedures and necropsies on large animals are ideally conducted in separate locations from the surgical suite but can be performed in a necropsy/perfusion room or in a specially designated procedure room. Room should be arranged to provide airflow from the least contaminated area to the most contaminated area.

### D.2 Animal Research Facility Support Space:

The ratio of animal facility support space to holding and procedure space is generally 2:1 or higher. Support space includes bedding and feed storage, decontamination or quarantine areas for incoming animals and materials, a laundry, feed preparation areas, administrative areas, break areas, meeting/training rooms, lockers for animal caretakers, gowning areas, cage wash, autoclaves, marshalling areas, diagnostic laboratories, pharmacy, storage areas

and housekeeping closets. Storage areas should include space for cage and rack equipment, general support supply storage, and locked cabinets for investigators to store small research specific items.

Shared use spaces may include surgical suites, imaging suites, behavioral suites, transgenic suites, radiology rooms and irradiator(s), in addition to the operational support spaces. Shared use, central or core facilities may be considered as part of support space or as part of procedure/holding space depending on how the program chooses to define the space. The definition of this space should be established early in the programming process to facilitate net to gross calculations.

## D.3 Office and Administrative Space:

Animal facility administrative areas should be designed using standard administrative space parameters. There may be a programmatic need for separate offices for government and contract supervisory staff. Administration offices should be located near the main animal facility entrance. This locates the management personnel in a position to observe the movement of personnel and equipment into or out of the facility. Guests, vendors and service people should have access to the animal facility administrative areas without entering the animal housing and support areas. Each veterinarian, manager and contract project officer should have a private office. Space should be allowed for office equipment such as copying machines and fax machines. A separate area for housing centralized computers and monitoring equipment should be considered. The administrative area should include conference rooms, a break room and access to toilet facilities that are separate from those used by the animal caretakers. Office and administrative space should have a positive pressure relationship to animal research facilities.

## D.4 Flexibility and Adaptability

Animal research facilities should be designed to maximize the animal holding capacity and accompanying utility services. The animal facility should be flexible and adaptable to accommodate changes in function and protocols without having to make major changes to the facility. Spaces should be designed to hold multiple species over time as protocols change. Individually planned or customized spaces are to be avoided. Flexibility in design of these critical areas provides for rapid accommodation of future programmatic changes and efficient space utilization.

## D.5 Expansion/Renovation Considerations:

Vertical and horizontal expansion of an animal research facility shall be considered during the planning phase. It must be possible to construct any expansion with minimal interference to the operation of the facility and the least disturbance to the animal population.

When planning for expansion, ensure that all utilities are compatible with existing utility systems, built-in equipment, etc.

## D.6 Planning Module

Modular planning techniques have traditionally been employed to provide for an adaptable facility. Modular planning schemes should be used, to the maximum extent possible, for animal housing and procedure space. Modular planning is based upon a concept of three dimensional units of space and services, which are used in a repetitive fashion for each type of function within the animal facility. The dimensions of the structural bay, both vertically and horizontally, must be carefully evaluated with respect to the laboratory planning module if the animal facility is component of the laboratory facility, mechanical distribution, and future expansion plans. The planning module must be developed on the basis of an evaluation of operations and protocols and the anticipated numbers and species of animals.

In animal facilities, the most common unit of space is the animal housing/holding room. Ideally, when planning a multifunction animal research building, the animal holding room modular size should be determined based on cage or rack system size. This scheme may or may not be similar in size and configuration to the standard laboratory module. The width of the animal room is determined by the number and types of animals, the way in which they are housed whether by cage or rack, and the cleaning methodology that will be employed. Room length is determined based on housing/caging options and minimum aisle width between racks but also must accommodate service space for sinks, cleaning equipment, and change stations etc. The height of the animal room and doors is primarily a function of the maximum rack height anticipated including rack fans. There must also be enough space above the rack to provide a uniform airflow distribution in the room.

Wherever possible, rooms should be clustered to provide separate zones for small and large animals taking into consideration the differences in rack dimensions, waste disposal requirements, acoustical and vibration requirements, care taking requirements, investigators, protocols, disease status, and airflow requirements.

Animal Facility Holding, Procedure and Support Module Variations: The length, width and height of the animal facility modules are dependent on the intended use of the space. There may be a need to a have a variety of different size small animal holding rooms with or without individual or shared anterooms. Animal holding and procedure suites are a combination of modules used for a specific research purpose. Within a suite, the rooms may be subdivided or positioned differently than in the general layout of the animal facility. Other support spaces such as the cage wash or the administrative areas are composed of multiple

modules without wall divisions to accommodate large pieces of equipment or open office space.

## E. Services and Systems:

Utility systems within the animal research facility must be capable of providing all the services necessary for scientists to conduct their research and for the animal husbandry staff to properly care for the animals. It is equally important that provisions be made for utility services to accommodate unanticipated demands brought about with new technologies or through changes in research protocols. A percentage of reserve capacity should be designed into the primary building systems to accommodate increased animal densities. All components of the utility systems should be planned and designed to allow all required access, maintenance and repairs without entering the animal holding or procedure rooms. Maintenance spaces should be configured so it can be expanded without displacing animal research functions whenever possible.

### E.1 Connection of Utilities to Animal Facility Space:

Utility services must be distributed to each individual space. The connection point of each service should be in a uniform position relative to the space and detailed to provide simple extension into the space without disruption of adjacent modules. These services may run in interstitial space, allowing animal holding or procedure space to change without increasing or upgrading capacity or location of central infrastructure systems. Changes would be primarily to terminal systems, i.e., piping and power connections to apparatus and equipment within the space.

### E.2 Services and Systems Distribution Concepts:

HVAC units serving animal facilities should be designed with redundant heating, ventilating, and air conditioning system arrangements or with standby equipment with capability to ensure continuous operation during equipment failure, power outages, and scheduled maintenance outages. It is acceptable to have a common air intake system for both animal holding and other parts of the building. The animal area exhaust system must be independent of the non-animal exhaust systems of the building.

Utilities and services including communication and information systems should be organized into specific zones, both horizontally and vertically, to provide distribution of systems and services that can be extended to each animal holding and procedure module. The choice of design and locations of the utility distribution system(s) is a product of utility function, cost effectiveness and ease of access for maintenance, future services, and remodeling during the life of the animal research facility. At a minimum, a percentage of the holding and pro-

cedure rooms shall be designed for interchangeability of use. The percentage and locations of rooms with drains should be determined during programming.

## E.3 Special Considerations for the Connection of Utilities to Animal Facility Space:

The following are special considerations for the connection of utilities to animal facility modules or space.

- Small animal holding rooms other than isolation cubicles shall each have a sink. Isolation cubicles are not required to have a sink but a sink should be located in an adjacent procedure location/room. In all situations hand washing sinks should be convenient to all holding locations. Large animal holding rooms shall have a sink outside the holding room area or suite.
- Non human primates and farm animal holding rooms and aquatic tank rooms require floor drains. Most animal rooms at NIH are not hosed down so drains should be avoided except in areas that may be converted to hold aquatic or large animal species in the future. When floor drains are present, consideration should be given to the appropriate size of the drain lines, maintenance of the drain traps, drain caps and flush systems and floor slopes to drains.
- The type of animal watering system should be determined (automatic or bottled) during programming. If automatic watering is not desired at the onset, consideration should be given to designing a system that can accommodate a percentage of automatic watering for possible future needs. Consideration should be given for the quality of water required. In some situations highly purified water such as RO may be required. In many cases there is an additional requirement for the treatment of the water prior to distribution (i.e. chlorination, acidification or neutralization). Remote monitoring of the water treatment process is required. In order to accommodate water treatment concerns appropriate equipment, piping and plumbing systems must be considered.
- Consideration must be given to steam connections, clean steam and reverse osmosis (RO) water with additional polishing systems in the cage wash and bottle filling area of the facility. Clean steam connections will be required wherever there is an autoclave. The users should also be consulted as to the need for RO water in dishwashers, if required and frequency of RO drops in procedure rooms.
- The racking/caging system for small animals should be determined as early as possible in the planning process in order to determine the type and number of duct connections. Different racking systems may have different types of connections. Alternate rack configuration will affect the placement of those connections. Considerations must be given to ducts above the plenum and the location and length of the exhaust taps. In addition, some racking systems are now designed with dynamic LAN line connections.

- Placement of electrical outlets and weatherproof or waterproof protective covering for the outlets should be carefully considered for all animal holding rooms. Electrical loads must be sufficient to accommodate all the needs of animal holding and procedure rooms. Ideally, electrical outlets servicing ventilated power turbo units and other equipment should be located high enough to prevent draping electrical cords, which may prove to be a safety hazard. Also racking systems shall be connected to the emergency power system.
- LAN line connections. Consideration must be given for the requirement of LAN connections within the animal holding room. In addition, some racking systems are now designed with dynamic local area network (LAN) line connections. Provide for at least one LAN connection for laptop use.

## F General Staffing Patterns of an NIH Animal Facility

The number of staff in an animal research facility will vary according to the size of the facility. Staff will include veterinary staff including a chief veterinarian and subordinate veterinarians, administrative staff, research and technical support staff, supervisory and staff level animal caretakers and support staff for feed and bedding preparation and cage wash. In addition, research staff will regularly enter and leave the facility.

## G. Space Descriptions

Animal research facilities present a wide assortment of planning challenges. The challenges range from differences in environmental requirements by species and building zones to the durability and water resistance of the architectural finishes to room flexibility that can accommodate a variety of species over time. This section of the manual presents information for the designer to use in planning the animal facility space requirements in relation to the species needs and caging systems and the zone the space occupies.

## G.1 Animal Housing and Holding Areas

Generally, any area where animals are held for more than 24 hours is treated as holding area. Housing/holding areas are usually located in a defined specific pathogen free (SPF) zone of the animal facility. However, there are instances where conventional housing is required for “dirty” animals such as a quarantine room or an area of the facility specifically for research using non-SPF or “dirty” animals.

In an effort to increase the facilities flexibility, it is essential to plan for both anticipated and potential species usage and rack and caging type. The animal housing or caging system chosen is one of the most important elements to consider in the planning process. Animal

housing and most procedure space should be carefully designed to facilitate animal wellbeing; meet research requirements; minimize experimental variables; and provide isolation from wide temperature and humidity variations, vibration, and noise sources .The caging system should provide adequate space to permit freedom of movement and normal postural adjustments; a comfortable environment; and an escape proof enclosure that confines animals safely with easy access to food, water, and ventilation. The caging system must also meet the biological needs of animals, e.g. maintenance of body temperature, waste elimination and reproduction. Ideally the chosen caging system should be: a) ergonomically friendly; b) of proven design and functionality; c) be durable; d) maximize available holding space; and e) be a standard shelf item with readily available replacement parts. All holding rooms must be designed to be easily cleanable and minimize pest harborage. Refer to Section 1-11 Integrated Pest Management. Consideration should be given to providing space to record data and to store records and supplies. All caging systems and animal holding rooms must meet or exceed all requirements out lined in the Guide for the Care and Use of Laboratory Animals, PHS policy and animal welfare regulations.

Small Animal Requirements: Small animals include mice, rats, hamsters, guinea pigs, reptiles, fish and birds. Each species will have different caging and environment requirements. Each species must be held in separate rooms or cubicles unless, in the case of rodents, ventilated racks are used to house them in order to provide separation of animals at the rack or cage level. Each rodent rack should provide for either bottle or automatic watering systems. Where isolation or quarantine space is required, space should be considered for a separate anteroom or procedure rooms.

A small animal holding room should be capable of housing different species at different times and in different caging systems. In most situations, holding rooms should not have windows although the doors may have an observation window or view port that can be made light tight or provided with red film. If windows are present within an animal holding room, systems must be in place to guarantee that the room's normal diurnal variation can be maintained. In addition, windows must be designed to preclude the visualization of animals from outside of the building and also to address security issues. Anterooms are optional for most animal holding rooms (dependent upon animal biosafety level), but should be considered on an as needed basis for the facility.

Small animal holding rooms should be located convenient to a central cage wash, but at a minimum they should be separated from the cage wash by a corridor. Likewise, to minimize the impact of noise and vibration the holding rooms should be separated from mechanical

rooms or other noise generating areas in the facility. This is particularly necessary for barrier areas where genetically sensitive animals are held.

Design features and finishes should encourage effective sanitation while at the same time be safe for personnel and durable. All surfaces should be water resistant, impact resistant and skid resistant. Electrical outlets should prevent shock hazards and have weatherproof covers in areas within the vivarium.

Each small animal holding room shall have a sink with hot and cold water within the room. There should be a place to hang a mop, ideally near the sink in each room. Consideration must be given to the various management styles, which may be utilized within each animal holding room. Some situations may require the use of biological safety cabinets (BSC) or a laminar flow change hood or transfer station. The impact of these systems and, in the case of ventilated racking systems, motors, must be considered in determining the rooms heat load and air circulation patterns.

Rodents: Rodents include mice and rats. Mouse cages may hold up to five mice per cage. Rat cages are larger than mouse cages and can accommodate up to four animals depending on size. Sometimes rats and mice are housed in the same room. Mixing species in a room should be avoided if at all possible. However, if this becomes necessary, ducted ventilated racks or other environment isolation equipment should be used.

Mice and rats are housed in “shoebox” type cages that are stacked in racks specifically designed for this purpose. There are numerous caging and racking systems on the market. Racks may be single sided and placed parallel to the room walls or double sided and placed perpendicular to the wall. Room configurations utilizing a combination of the two systems have also been used with success. There are also systems that can be arranged in a “T” formation. The proposed rack layout will determine the projected facility holding capacity. Ideally, the rack arrangement should allow adequate space for a caretaker to roll a cart up to or between the racks for animal transfers, bedding changes, and for maintenance items that may be include feed barrels, mop racks and trash cans. Consideration should also be given to providing a flexible layout that can accommodate someone with a disability to maneuver between the racks if required. The minimum recommended space between racks is 915 mm. Some animal facility programs may require a biological safety cabinet or a change station in each holding room to make cage and bedding changes, rodent transfers or to perform minor procedures. The designer should allow room for a changing station in addition to the holding racks when this need is identified in the program. Consideration should be given for the additional heat load provided by change cabinets or ventilated racking systems.

Reptiles and Amphibians: Reptiles and amphibians can be held in rium type glass or plastic tanks or they can be held in modular flexible species holding rooms. Temperature and humidity control and lighting are the only special requirements for reptiles. The temperature should range between 20-29.5$^{O}$C and the relative humidity should range between 33%- 60%. The users should determine whether or not they want UV light in the room. UV light provides vitamin D to the reptiles. If UV lights are installed, a UV warning light must be installed outside the room in addition to an auto-off switch that is activated upon opening the door.

Birds: Most species are held in small animal cages or they can be held in modular flexible species holding rooms. The type of bird containment will depend on the species, the study and the investigator's requirements. Some birds might be held in cages while other species might require an aviary that mimics their natural environment. Although a drain is not required in a bird holding room, the room cleaning method must be closely reviewed. If the room will be hosed, then the floor shall have a drain.

Aquatics: Aquatics include fish, sea urchins and amphibians. The trend in aquatic tank holding rooms for fish is to have a single large room that can hold many tank racks with integrated water circulation and filtration systems. However, there may be different requirements for other aquatic species. Lighting shall be timer controlled for circadian rhythm studies. Amphibians are sensitive to temperature differences and may require "sunning" areas. Noise and vibration can adversely affect aquatic species and should be controlled or buffered as much as possible.

Water is the life support medium for aquatic species. The water system supporting the various components of the system must be sized properly. A major concern for the designer of an aquatic facility is the water weight. Aquatic holding rooms must be designed to structurally support the load.

Water temperature, quality, pH, degree of hardness and salinity must be tailored to the specific aquatic species and must be closely monitored to avoid disastrous effects on the population. The levels of ammonia, nitrates, chlorine, dissolved oxygen and carbon dioxide in the water must also be monitored.

In some cases, a percentage of supply water can recirculate. Recirculation parameters shall be discussed with the user representatives designing the building. The location of pumps and other mechanical equipment associated with the aquatic facility is a critical design feature and shall be located remotely from the holding rooms so as not to create noise and vi-

bration. Appropriate filtration should be considered for the removal of particulates and nitrogenous wastes. A flow monitoring system should be incorporated in the system to detect a loss in pressure or decline in water levels. Emergency power should be considered for the pumps and lights in the aquatic facility. Floor drains should be installed in all tank and procedure rooms where aquatic species will be housed. Floor drains are essential and flood proofing is an important feature to consider in design especially if the holding tanks are on an upper floor. Floors should be sloped 3 mm to 10 mm to the drain. Drains should be rust proof and flush with the floor. Consideration should be given to providing some way of trapping and removing debris from the drain opening (i.e. removable basket). Other flood proofing considerations include putting a small berm and a tight seal sweep at the door base. All ceilings, walls, sills and floors should be water resistant. All lighting fixtures should be splash resistant. All electrical boxes and conduits should be corrosion resistant and splash resistant UL listed wet location minimum 85 PSI or minimum IP65 rated. The HVAC system should work in tandem with the water supply system in controlling the room and water temperature. Note that in order to maintain the desired water temperature; the room temperature may not be ideal for those who have to work in the room.

In order to define space usage in an aquatics facility, the following shall be considered and provided per program requirements:

- Space for the nursery, procedure space in small rooms off the tank areas, and for raising aquatic food (i.e., shrimp).
- Space for preparation of dry food. Space shall be allocated adjacent to the water tank holding rooms for mechanical system components, live food production, supplies, and additional procedure areas.
- Space for a shop with storage capacity on equipment.
- A quarantine area may be required for incoming animals even in a facility that breeds its own study population of animals. The location of the water pumps and recirculation piping shall have a major effect on the design of this area.
- A sink and adequate bench space for procedures and staff activities per each module.

An aquatics facility may require easy access to a fume hood because highly carcinogenic and teratogenic chemicals are used to create mutations in fish. A holding area may be required close to the fume hood for short term holding of fish that have been treated with mutagens. These needs should be discussed with the potential users.

Insectary: At the NIH, insects are studied as the carriers (vectors) of transmissible human diseases or for genetic research related to human disease. Examples of insects used at the NIH are mosquitoes, sand flies, ticks and fruit flies. Design requirements may vary for different insect species but the general concepts for an insect breeding and research lab are the

same for all species. The following general design criteria should be addressed when planning any insectary.

- Temperature and humidity control
- Light control
- Pest management methods
- Use of nonporous materials in construction
- Methods of insect containment
- Species specific breeding requirements
- Cold storage
- Research/lab supply storage
- Food preparation requirements
- Adjacent research procedure space requirements
- Uniform lighting throughout to prevent shade and shadow including under counter areas, corners, etc.
- An anteroom with inward directional airflow for airborne insects.

A major health and safety concern in an insectary is the inadvertent release of infected or genetically manipulated insects into the environment. Insect containment can be managed by using carefully controlled procedures in a facility that is designed well. Access to the insect barrier shall include a series of sealed, controlled access doors separated by small vestibules containing devices appropriate to trap the species used in the facility. These may include wall mounted light traps or temperature control devices to produce an environment such that an insect could not survive passage through the space. Mosquitoes are slowed at temperatures between 2-10$^{O}$ c. If a mosquito were to escape the barrier into a cold vestibule, it would drop to the floor and eventually die.

Insect breeding rooms may have a temperature range of 10-28$^{O}$C and a relative humidity of 75%. Surfaces within breeding rooms should be smooth, nonporous white materials. Ceilings should be low 2.3 m (7'-6") to allow recapture of escaped insects and ease of cleaning.

Environmental rooms must be designed with tightly sealed, weatherproof electrical outlets and fixtures. Drains are not recommended as they can harbor unwanted pests or serve as uncontrolled breeding areas. Doors to the facility should be of solid core construction. Shelving in breeding rooms or insect procedure rooms shall be stainless steel wire open construction to eliminate any hiding places for contaminating insects or other pests.

Lights in breeding rooms must be provided with timer and dimmer controls to recreate natural environment conditions that are essential for breeding.

Screened doors shall be used as necessary within insect barrier areas. The screen material and mesh size are important factors to consider. The mesh size will be dependant on the insect species housed in the area. The screen material must be rust resistant and durable.

Rabbits: Rabbits fall in a category between small and large animals. They are considered large animals because their requirements for surgery follow large animal guidelines. However, rabbits are typically housed in the rodent space of an animal facility. Rabbits are typically housed one per cage. Rabbit racks are designed specifically to hold rabbit cages. A typical rack will hold six to eight rabbit cages. Larger cages are used for breeding. For rabbits weighing up to 4 kg, each rabbit requires .28 $m^2$ (3 nsf) of floor space. For rabbit weighing over 4kg, each rabbit require .37 $m^2$ (4 nsf) of floor space. Rabbit cages contain waste pans that must be changed frequently (perhaps 3 times per week). Rabbits may spray corrosive urine outside their cage. Cleaning requirements for the room and descaling the racks become an issue where rabbits are held. Wall and floor surfaces must be very durable and cleanable in rabbit rooms because frequent scrubbing is necessary to remove urine. Consideration should be given to a pre-filter/grid system at the exhaust because frequent filter changes will be required due to a large amount of fur shed. Rabbit holding rooms (or spaces with other species that shed excessively) should be provided with a pre-filter/grid system at the exhaust located no higher than 1 370 mm (5'-0") from the floor. The rooms will have temperature, humidity and lighting requirements. Adequate aisle space has to be allowed for ease in changing out the pans and working with larger breeding cages

Large Animals: Large Animals include nonhuman primates, cats, dogs and farm animals. In the case of some large animals, especially nonhuman primates, consideration should be given to providing natural light, adequate exercise areas, group housing, means for animal communication, and well equipped play areas with toys, games, and televisions. This must be undertaken without sacrificing safety, and may depend upon the nature of the research. Ideally, the large animal holding rooms and activity areas should be designed to provide an enriched, visually complex environment for nonhuman primates and other species where data is available to suggest a benefit.

Since large animals may be noisy, they should be housed away from quieter areas of small animal rooms, administration spaces, and research laboratories. In some situations, anterooms are also recommended to minimize the potential of releasing escaped animals into the rest of the colony. Each cage should provide for either bottle or automatic watering systems. Consideration should be given to self-flushing drains for some species holding rooms. Ideally, dogs, sheep and pigs should be provided with runs if they are to be held for a long period of time. The size of the run utilized should at a minimum meet the requirements for daily exercise of the animals.

Nonhuman Primates: Nonhuman primates are categorized as Old World i.e. macaques, cynomologous, and baboons or New World i.e. marmosets and owl monkeys. There can be great variation in the size of the non-human primate even within the same species. Non-human primates may be housed in individual cages but they also may be paired or group caged. Group housing may be used in some instances for infants or juveniles.

The size of a nonhuman primate room must accommodate working safety considerations. Animal caretakers must be able to work within the holding room but be out of reach of the nonhuman primate. Aisle space between the cages will be determined by the species and caging and racking systems. This dimension will exceed 915 mm (3'-0") to prevent the non-human primate from reaching the worker if they are standing in the middle of the room. Space should be allowed between housing racks and cages to permit maneuverability. This space has an impact on the overall room dimension.

Space in group cages should be enriched with structures such as resting perches, visual barriers and, when housing some species, shelters. Some species should be provided items for swinging or climbing. They are very social animals. The current philosophy is to provide enrichment areas for them to play and communicate. Enrichment can include providing the non-human primates with the ability to view movement through windows into the general corridors so that they can see the caretakers or to the exterior of the building. In some circumstances thick lexan panels in lieu of traditional caging may be considered in some nonhuman primate faculties for enrichment and socialization.

Nonhuman primates are noisy, messy and destructive animals. Therefore, sound attenuation and durable finishes are important considerations in the design process. Exterior windows and holding room door lites must have adjustable shutters or blinds to allow the animal rooms to be light tight if necessary and to aid in the maintenance of normal diurnal variation.

Dogs: Dog species used for biomedical research are commonly medium sized breeds such as a beagle but larger species i.e. foxhounds are not uncommon. Dogs are noisy and messy so sound attenuation and durable finishes are important considerations in the design process. Flush drains are required. Facilities that house dogs may have outdoor runs for enrichment of the animals. Dogs should be able to see other dogs and other movement so partitions can be of the chain link variety. Consideration should be given to providing design elements that facilitate socialization of the animals.

Farm Animals: Farm Animals used for research at NIH include sheep, pigs, goats and occasionally cattle and horses. Research farm animals may be housed indoors or outdoors. Farm animals are often used to test surgical procedures that require long term observation of the animals. Pre and postoperative holding areas may be required. Indoor facilities must have walls that can withstand the forces these animals can exert on them; and the entire structure shall be designed to support the animals planned to occupy the space. Farm animals are noisy and messy so sound attenuation and finishes are important considerations in the design process. Flush drains or trench drains will be required.

Cubical Housing: Cubicles are small rooms or containment compartments within a larger room or suite of rooms. Cubicle housing may be used for isolating animals of different health statuses, for conducting timed day/night studies, for separation of different species or for specialized barrier areas. Cubicles offer the advantage of isolating a small segment of the animal population and permit housing of multiple species in a single room. Cubicles are particularly useful for quarantine of incoming animals and may preclude the need for a separate quarantine room. Cubicles are also useful in the containment of hazardous substances used in animal studies, provide an added degree of security, and reduce odors and allergens. Cubicle housing areas should be designed to have either positive or negative air pressure in relation to adjacent spaces based on intended use of the cubicle. If the cubicles are prefabricated units, they can be readily disassembled to convert the room to other uses. Ideally, cubicles should be designed to accept two single-sided rodent racks or one double-sided unit or one non human primate racking unit. Although management may decide to utilize static non-ventilated cages within the cubicle, cubicles should be equipped with two exhaust drops to be used if ventilated caging is used in the area. If overhead doors are used on this type of space, consider providing automatic door operators, which must be provided with safety devices that prevent injury to the operator, which must be provided with safety devices that prevent injury to the operator.

A higher level of protection can be attained through the provision of individual air supply and exhaust in each cubicle. Air may pass through a high efficiency particulate air (HEPA) filter at the supply, exhaust, or both. Each cubicle may also have its own lighting and watering system. Access to a manual over ride must be restricted through the use of a key or card key system. Uniform lighting is ideal throughout the cubicle but because cubicles are small light may not reach the back of the holding rack. Therefore considerations should be given to specifying vertical fluorescent lighting to be installed in the corners of the cubicle in addition to ceiling lights. If vertical lighting is utilized, the bottom of the tube should be specified to be 457.2 mm from the floor. The fixtures must be sealed and gasketed.

Containment Suites: As a minimum, all animal facilities at the NIH shall be designed as ABSL2 facilities. Containment suites shall have negative air pressure relative to adjoining areas. For specific requirements refer to the Center for Disease Control and Prevention (CDC) NIH publication "Biosafety in Microbiological Laboratories" for animal biosafety level (ABSL) planning and design

Isolation Areas: Isolation cubicles should be provided to house animals that may have an infectious disease or animals that may be more susceptible to disease (i.e. immuno- compromised, etc.). Ideally, cubicles should be designed to accept two single-sided rodent racks or one double-sided unit or one NHP racking unit. Although management may decide to utilize static non-ventilated cages within the cubicle, cubicles should be equipped with two exhaust drops to be used if ventilated caging is used in the area. Isolation rooms should be on the "dirty" side of the animal facility, perhaps near the necropsy/perfusion room.

Procedure Rooms: Animal procedure rooms may be either shared or dedicated. A shared procedure room provides space for working with animals from multiple animal rooms and frequently involves multiple investigators, and possibly more than one species. Dedicated animal procedure rooms provide space for working with animals maintained in a single room or a small cluster of animal rooms that may have direct access to the procedure laboratory. Procedure rooms should be equipped with a fume hood and/or BSCs, sink with eyewash, stainless steel counters with downdraft sinks/tables for rodent surgery, exam lights, refrigerator and wall-mounted or mobile cabinets. Alternatively, ducted BSC can be considered for areas that use small amounts of chemicals or radio-isotopes. Class II, B1 or B2 BSCs may require increased exhaust and make-up air, which is more energy intensive.. There should be sufficient electrical outlets to support all anticipated equipment. Central gas (oxygen, carbon dioxide, etc.), a passive gas scavenger line, vacuum and high pressure air may be needed in some or all procedure rooms. A low bench top may be needed for either a desk surface or a microscope. Procedure rooms should be designed so that they can be converted to animal holding rooms.

Behavioral Testing Rooms: The requirements for behavioral testing rooms will be driven by the species to be tested. All behavioral testing rooms should have the same HVAC as other animal holding/procedure areas. All behavioral testing rooms should be light tight, acoustically protected, and have IT connections to data collection areas outside of the testing room. All testing room requirements shall be reviewed with the users.

Rodent testing rooms may require deep countertops at desk/table height to hold special equipment. The rooms should have shelving for storage of testing equipment. Floor material in rodent testing rooms can be shall be epoxy. Rodent testing rooms shall have light cycle controls. At least one rodent testing room should be capable of holding a water tank. This room should have a sink and a drain. The floor in the water tank room should be of a water-proof material. The water tank rooms will require a video camera mounted above the tank with connections to a data collection system. If the data collection system is to be within the tank room, a visual barrier must protect it so that light or movement from video screens or personnel does not distract animals. Each wall of the room should have either a light box or a tack board to mount cue cards.

Nonhuman primate testing rooms often require very sophisticated electrical connections. Extra power lines and clean data and LAN lines are needed for computers. Several computer network connections may be required. Cable trays, if required, should be mounted around the perimeter of the room at ceiling level. Nonhuman primate testing equipment may be robotic and may require structural considerations. Lighting needs may vary according to the type of testing to be done in the rooms. Light cycle controls may be needed. Cameras and projection equipment will be used in some of the rooms. Nonhuman primate testing rooms may be individual rooms specifically designed for behavior testing or they may be prefabricated testing chambers that are assembled on site. Some testing chambers may require individual exhaust drops while other test boxes contain fans and do not require additional ventilation considerations. This need should be discussed with the user.

## Summary Space Schedule Animal Housing

The designer should develop an overall planning module for animal holding rooms based on the proposed racking and caging systems.

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Animal Room (Small Animal Housing) Mice, rats, hamsters, guinea pigs, and rabbits | Number and species of animals and racking systems determines the size of the space. | Cages or racks, change station or BSC, sink, mop racks, feed barrel, bedding barrel, space for cart, and counter space | 3.0 (9'-0") |
| Insectary | Species dependent | Possible environment control room. Stainless steel wire shelving, smooth nonporous white surfaces. All openings must be watertight. No drains. May need screens partitions; and light timing control. | 2. 3 (7'-6") |
| Animal Room (Large Animal Conventional Housing) cats, nonhuman primates, dogs, and | Number and species of animals determines the size of the space. | Cages, runs, and socialization areas. Hand wash sinks in the holding room.Work areas must be outside of the holding room. | 3.0 (9'-0") |

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Farm Animals | Number and species of animals determines the size of the space. | Pens. Indoor holding area must have trench or flush drains. | 3.0 (9'-0") |
| Animal Room (Cubicle Housing) | Number and size of the housing unit or degree of isolation required determines the size of the space. | Cubicles or flexible film isolators | 3.0 (9'-0") |
| Procedure Room | 22.68 (242) | Fume hood, BSC, counters, sink, exam table, refrigerator, wall cabinet, flammable storage cabinet and under counter cabinets. | 3.0 (9'-0") |
| Rodent Behavior Testing Room | 22.68 (242) | Deep countertops at desk/table height to hold special equipment, shelving for storage of testing equipment; sink and a drain when a water tank is specified. | 3.0 (9'-0") |
| Nonhuman primate testing rooms | Equipment and testing protocol determines the size of the space. | Nonhuman primate electronic testing equip-ment and cable trays | 3.0 (9'-0") |

## G.2 Diagnostic/Pathology Laboratory

Diagnostic/Pathology Laboratory: Diagnostic laboratory services are ancillary to the treatment area and facilitate diagnosis of animal health status. The services may include gross and microscopic pathology, clinical pathology, hematology, microbiology, clinical chemistry, and other appropriate procedures. The space will be equipped with stainless steel countertops with an integral sink, a refrigerator, downdraft tables, hand wash sink with eyewash, and casework. $CO_2$ is the only central gas that may be required the need for compressed air medical grade oxygen or vacuum should be discussed with the user. Specialized fume hoods may be required as determined by the users. A ducted biosafety cabinet (Class II type B1) or a non ducted BSC may be required for examination of infectious specimens. Low bench tops may be required for microscopes. The diagnostic laboratory will be equipment intensive. There should be adequate electrical outlets to handle many small tabletop pieces as well as larger pieces such as incubators or centrifuges or scintillation counters. The room pressure should be negative by a minimum of -12.5 Pa (-0.05" w. g.) in relation to adjoining areas

Necropsy/Perfusion: This area provides space for examining deceased animals or performing terminal procedures. It is ideally located either near the diagnostic pathology lab or on the circulation route that is used for waste to exit the facility. It must be equipped with a downdraft table (sized for species held in the facility) that is equipped to collect hazardous chemical waste, a stainless steel counter, eyewash, sink, and casework. A fume hood or

ducted biosafety cabinet may be needed. $CO_2$, gas, vacuum and a gas scavenger line shall be provided. Provisions should be made for carcass storage. Either a refrigerator/freezer in the room or, for large animals, adjacent walk-in refrigerators are recommended. Imaging equipment may be used in the room. A light box may be required. The room pressure should be negative by a minimum of -12.5 Pa (-0.05" w. g.) in relation to adjoining areas.

Summary Space Schedule Diagnostic/Pathology Laboratory

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt m (ft) |
|---|---|---|---|
| Diagnostic Laboratory | 12.96 (140) | Countertop, s/s, raised rim, w/integral sink and splash backs, casework, refrigerator or cold room, freezer, storage gas cylinders, down draft table, fume hood and BSC. | 3.0 (9'-0") |
| Necropsy | 11.88 (130) | Down draft necropsy table, counter, sink, base, trimming table and wall cabinets, refrigerator, freezer, light box, and gas scavenger. | 3.0 (9'-0") |

## G.3 Animal Surgery

Functional areas for surgery should include a surgical support area i.e. storage, instrument prep, lockers and janitorial rooms; an animal prep area, a surgeon prep area i.e. scrub area, lockers/change room, restroom; operating room(s), and post surgical recovery/intensive care area. Intensive care/recovery rooms should be located near the surgical suite. The surgical suite should be located away from high traffic corridors and potential sources of contamination such as cage wash, necropsy, and waste storage. Ideally, separate locker, housekeeping, and toilet facilities should be provided as an integral part of the surgical suite. The surgical suite should have windows for observation and an intercom system connected to all rooms of the suite. Ideally the suite should be an isolated unit with controlled/restricted assess. Surgical suites are designed differently based on the types of animals used. Survival surgery for small animals may be conducted in procedure rooms or in operating rooms.

Locker Room: This area provides space for surgical personnel to change before and after surgery. Lockers should be provided for short term storage of personal items. Consideration should be given to planning a janitor's closet (with a floor mounted mop sink) and a toilet room in this area.

Surgeon Scrub Room: This room shall have hands free direct access to the surgical suite/operating rooms. It should be equipped with a hands free scrub sink and disposable

scrub brush dispenser. The scrub area shall be an isolated area, not utilized as a thoroughfare for animals or supplies.

Animal Surgical Prep Room: This area provides space for holding and preparing the animal subject for surgery. The room should have two separate doors to provide one way traffic flow into the surgical area and out to the general circulation/housing area. It should have direct hands free access to the operating suite/room. The prep room will be equipped with a procedure table, storage cabinet, stainless steel counter, sink, eyewash, with wall cabinets. A down draft table, as well as a wet prep table may be required. The prep room should have vacuum, a waste anesthesia gas scavenger line, compressed medical gas lines (i.e. oxygen, medical grade air, nitrogen, etc.) are required at each procedure table/location. A controlled access drug box should be considered in the prep room. There should be space for a refrigerator and a portable anesthesia unit.

Operating Room: This area provides space for surgical procedures on animals. In order to maintain a sterile environment, consideration should be given to a door lock system that will lock the operating room door from the outside if the door to the adjacent room is open. Compressed medical gases (i.e. oxygen, medical grade air, nitrogen, etc.), waste anesthesia gas scavenger units, and vacuum lines shall be provided. Overhead surgical lights and a double light box to view x-rays are suggested. Operating rooms are equipment intensive and require additional electrical outlets to support fixed and mobile equipment needs. All of the operating rooms should have easy access to a central fluid warming cabinet and contain a viewing window to the exterior surgical suite corridor.

Recovery Room: This area provides space for animals recovering from surgery and the effects of anesthesia. The recovery room/cubicle shall be designed to meet the requirements of non human primates or other large animal intensive or post operative recovery care. Each room or cubicle should be able to house one or more specialized environmental support units designed to provide a controlled environment (i.e. oxygen tension, humidity, temperature, etc.) or single cages or holding racks depending on the species to be accommodated. Ideally the room should have two doors to provide one way movement from the surgical suite and out to the general circulation to return the animal to its housing unit. The room or cubicle should be equipped with a bench top, sink and an oxygen line. Compressed medical gas, vacuum, as well as a refrigerator and drug storage areas is required. A controlled access drug box should be provided. Desk space should be provided for computer monitoring equipment and charting area.

Surgical Supply and Surgical Work Room: This room will provide space for surgical supplies and work space. It should have direct access to the operating room and the general circulation corridor. It will be equipped with lockable casework, sink cabinets, and sterilizers.

The room is organized with one way flow from dirty to clean. Cleaning equipment such as sinks, washers, ultrasonic cleaners, and autoclaves are accessed from the dirty side, with instrument pack, prep, and storage on the clean side, toward the operating room. RO or DI water may be needed for instrument wash equipment. Clean steam is required for the sterilizers. The designer should evaluate the need for gas, heat and steam sterilizers/autoclaves within the facility. If EtO sterilizers are required, special exhaust must be provided.

Summary Space Schedule for Animal Surgery

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Animal Surgical Preparation Room | 11.20 (120) | Procedure table, storage cabinet, counter, sink, eyewash, w/wall cabinets, fluid-warming cabinet central gases, control substance safe, and refrigerator. | 3.0 (9'-0") |
| Operating Room | 18.80 (200) | Operating table, portable anesthesia machine, instrument table, suction cart, isolated power unit, major surgical light, medical gas dispenser, gas scavenging device, x-ray illuminator, special monitoring equipment and white board. | 3.0 (9'-0") |
| Scrub and Gown Room | 8.75 (94) | Surgeon's scrub sink, casework, and storage cabinets. | 2.4 (8'-0") |
| Locker Room | 0.3 or (3)/ person | Full length lockers and benches | 2.4 (8'-0") |
| Rest Rooms | Size per plumbing code | | 2.4 (8'-0") |
| Surgical Work and Supply Room | 13.50 (145) | Case work, sink, instrument washer, sterilizer, and tables | 2.4 (8'-0") |
| Post Operative Intensive Care (Recovery) Room | 11.20 (120) | Cage or rack, counter w/sink medical grade oxygen source and wall cabinet, refrigerator, and gas tank storage | 2.4 (8'-0") |

## G.4 Pharmacy

A pharmacy area shall be provided in the vicinity of the procedure room and surgery suite but it does not have to be within the surgical suite. It shall contain an appropriate level of security in addition to a drug vault and a controlled access drug box. It should have some bench space, a desk area, a sink and a refrigerator. Lockable cabinets should be provided for drug and supply storage. Data lines should be provided in the area for inventory control. High density movable storage systems should be considered for pharmacy storage. A ductless alarm should be considered.

Summary Space Schedule for Pharmacy

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Pharmacy | 11.20 (120) | Drug vault, controlled access drug box, work surfaces w/binder bins & lateral files, sink with eyewash, and refrigerator | 2.4 (8'-0") |
| Pharmacy Storage | 14.00 (150) | Lockable cabinets, high density movable storage system | 2.4 (8'-0") |

## G.5 Whole Animal Imaging Equipment Spaces, Radiographic Suite and Irradiator Room

The design of whole animal imaging systems such as MR, X-Ray, PET, CT and SPECT shall consider serviceability and decontamination from maintenance and biosafety standpoints. Consideration shall be given to whether portions of the equipment shall be located outside of containment for ease of maintenance and serviceability. Should any portion of the equipment be located outside of containment, a containment barrier that integrates the imaging equipment and the animal interface shall be required.

The radiographic suite consists of a darkroom, control booth, and radiographic room. It should be convenient to the surgical suites and accessible to other parts of the animal facility. It is common for facilities to require more than one style of x-ray unit (i.e. fixed table mounted unit, dental, rodent, etc.). The designer must establish the requirements of the facility and design the suite accordingly. The X-ray equipment, animal subject, and entry should be visible from the control booth. Radiation safety shall be consulted for any special shielding requirements.

Darkroom: The darkroom provides space for developing X-ray film and may house an automatic film processor or developing tanks, sink, film bin and light-tight loading bench, countertop, red light, and wall mounted film illuminators. A silver recovery system must be provided if required by the processing equipment. The dark room should be equipped or designed to prevent flooding of rooms adjacent and below the space and shall include the means for detecting floods. The room must be equipped with a lightproof door and a warning sign. An electronic interlock should be provided that prevents the red light from lighting and entry door from opening while the film bin is open. Entrances to darkroom and the internal layout of the darkroom must provide access to individuals with disabilities. Based on some facility layouts, multiple darkrooms may be provided within animal facility support spaces.

Radiographic Room: This room provides space to X-ray animal subjects and will house radiographic and fluoroscopic X-ray unit(s) with table, wall mounted film illuminators including spot illuminators, and wall mounted storage cabinets. Storage may be required for film archives and portable imaging equipment such as ultra sound machines. Provide a pass-thru interlocking box for film transfer between the radiographic room and darkroom. Specialized power requirements of the individual machine must be taken into account in the design of power distribution. Some counter space should be provided. The specific requirements of the units to be installed in the area must be determined by the designer. Shielding of all walls and doors must be provided in accordance with the NIH Division of Radiation Safety. An electronic interlock system between the X-ray equipment and entry door lock will be as follows:

- The electric lock is activated by X-ray equipment
- X- ray equipment shall not operate unless the entry door is closed and locked.

See Environmental Management/Radiation Safety Section 1-9-20-F.9 “Radiation Producing Equipment and/or Machines.”

Control Booth: This booth provides protective space for personnel to control the X-ray unit and it is located in the radiographic room. The NIH Division of Radiation Safety shall review and approve all design documents and inspect all construction relative to the radiographic equipment.

Irradiator Room: A cesium irradiator is used primarily to irradiate rodents or sterilize tissue culture specimens in order to conduct further research. An irradiator is a large piece of equipment with a radioactive source housed within the unit. The unit can weigh up to 3,700 Kg. If the irradiator will be transported to its permanent location via an elevator, the elevator must have the capacity to accommodate the irradiator’s weight. In addition, the approach to the room must be direct and free of obstacles that may prevent installation of the equipment. Appropriate electrical connections are required and should be on a backup generator. The room housing an irradiator must have a controlled access door that is locked at all times. Provide two independent entrances, one via the vivarium for animals, and one for research personnel needing to irradiate cell cultures.

The irradiator room does not require special shielding because the shielding is built into the instrument. The room should have some shelving and a bench top work area. IT connections are required for a local computer to collect data while the unit is running. The Division of Radiation Safety must be consulted and must approve the room plans and the access route for the irradiator.

NMRI: Magnetic and RF shielding requirements shall be verified with equipment manufacturer and shielding consultant. All shielding requirements must be coordinated with containment penetrations. Coordination of electrical and plumbing piping shall be performed to minimize the effects of magnetic or RF interference inside the shielded system. The effects of structural components on shielding design (rebar, steel joists, etc.) shall be considered. Proximity of NMRI to adjacent equipment or areas of ferrous activity (loading docks, cart movement, etc.) shall be reviewed for additional shielding and separation requirements. Ceiling heights may be increased due to shielding requirements and may have an impact on overall floor to floor heights.

CT/PET/SPECT: Lead shielding requirements shall be verified with equipment manufacturer and shielding consultant. Lead shielding of penetrations shall be coordinated with containment requirements. Isotope injection and animal recovery areas shall be determined by program.

Summary Space Schedule for Radiographic Suites, and Irradiator Room

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Dark Room | 5.76 (62) | Automatic film processor, sink, film bench and loading bins, counter top, and wall mounted film illuminators. Must be accessible to persons with disabilities. | 3.0 (9'-0") |
| Radiographic Room | 22.95 (247) | Radiographic and fluoroscopic x-ray unit w/table, wall mounted film illuminators, and wall mounted storage cabinet. | 3.0 (9'-0") |
| Irradiator Room | 11.00 (118) | Cesium Irradiator, lab benches, data ports or LAN connections, and desk space | 3.0 (9'-0") |
| NMRI | Equipment determines the space | NMRI System: magnet, shields, computers, transmitters, receivers etc. | * |

* Equipment determines the height

## G.6 Decontamination and Receiving

This space is used to decontaminate the containers in which newly received animals and materials arrive so as to reduce the transfer of vermin or contamination from outside the facility. Animals may be transferred from their delivery containment unit into clean holding units at this location or they may be moved to the holding room to be transferred locally. If equipment or other materials will be chemically decontaminated in this area, consideration should be given to providing a grid floor with a chemical collection unit under the grid that can automatically neutralize the chemicals before they enter the sewage system. A large drain and hose bib with backflow preventer will be required for this space if materials will be chemically decontaminated. The space should be located between the animal loading dock

and quarantine. It shall be equipped with a sink with eyewash, drain, hose bib with backflow preventer, desk and bench top. Adequate storage should be provided for both waste and clean equipment. Caretakers in rodent receiving areas may use temporary isolation cabinets to separate animals from different sources.

Quarantine Area: Incoming animals may be quarantined prior to entering the animal holding area. Self contained cubicles may be used for small animals held in the facility. Each cubicle may have its own exhaust and watering system. A pass through autoclave shall be considered for a larger quarantine room. The quarantine room shall be located close to receiving and the cage wash. It should have a sink, bench work area and shelving, and exam lights. A small diagnostic lab with bench top centrifuges and other lab equipment may be required in close proximity to the quarantine room.

Vestibules: Vestibules should be located as required to prevent contamination of animal holding areas and clean areas of the animal facility, for sound isolation, and for security. Vestibules may be appropriate at the point of entry into the facility, into a suite of isolation rooms, between areas that hold different species or between animal and administrative areas. Doors are to be equipped with bristle type door sweeps. Consideration should be given to provisions for staff to gown/degown at entry vestibules. A cross over bench or pull down seat should be considered in gowning areas as well as space to store clean gowning paraphernalia and discard bins.

## Summary Space Schedule for Decontamination and Receiving

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Animal Receiving Room | 11.20 (120) | Countertop, stainless steel (s/s), raised rim, w/integral sink and splash backs, casework, s/s exam table, refrigerator (domestic type), electronic animal weighing scale, and exam light. The following equipment is only applicable when more than the minimum net area (11 $m^2$) is provided: bathtub & floor mounted electron animal scale. | 3.0 (9'-0") |
| Quarantine Room | 11.40 (123) | Self contained cubicles or flexible film isolators, exam area and sink. | 3.0 (9'-0") |
| Vestibules | | Shelve storage for gowning, separate waste bins | 3.0 (9'-0") |

## G.7 Cage Wash

The cage wash houses equipment for cleaning and sanitizing animal cages, trays, lids, and water bottles. In addition, the cage wash area may house bedding disposal and bedding filling equipment and storage for clean bedding. During the planning phase, the method and route for feeding, bedding delivery and bedding disposal between the loading dock and the cage wash must be defined. Automated delivery and discard systems for bedding, food and waste are available and should be considered for large facilities. These systems may have special space requirements at the loading dock and in the cage wash area. The cage wash should be convenient to animal holding but distant from administration offices and personnel areas.

The cage wash equipment may include a bottle washer, a cage and rack washer, tunnel type washers, acid neutralization tanks, robotic equipment and an autoclave. The auto clave should be of sufficient size to contain full size or multiple cage racks. In some applications, a large, pass-thru autoclave with controls on both sides may be adequate to serve the needs of both the clean and dirty sides. This may eliminate the need for duplication of expensive capital equipment. The autoclave should be provided with “clean” steam to extend the useable life of the equipment. Provide sufficient space for maintenance needs to include exhaust of the mechanical space and sufficient lighting levels. The species housed in the facility, the capacity of the facility, the number of wash cycles per week, the number and duration of staff shifts, and redundancy/capacity of other washers determine the equipment type, size and complexity.

The cage wash area should be divided into a "dirty" side and a "clean" side. A third area containing the wash equipment should be considered in large cage wash operations between the clean and dirty sides. There should be no personnel access between the two sides. The sides may be divided by a glass or stainless steel partition with a telephone or paging system for communication.

Access to the dirty side should be through double doors opening in the direction of traffic. Automatic openers should be installed to control the doors. The doors should be impact resistant and have door sweeps. The dirty area must be designed for wash down activities. Linear space is needed to marshal incoming cages and racks; for dumping bedding; cage break down; emptying bottles and loading washers. The dirty area should be equipped with a sink, bedding dump station, waste disposal equipment, automatic water manifold flush

station, chemical neutralization, pre-wash stall with a grid floor, a water fountain and emergency eyewash and shower. A pit may be required to prep or descale the racks and cages.

The clean area is equipped with a large autoclave, bedding dispenser, animal drinking water flush station, and water bottle filler. Linear space for marshalling is also required on the clean side. A unisex toilet room and water fountain should be provided in both dirty and clean areas. Both sides should be designed to promote proper cleaning and minimize pest harborage.

Cage and rack washers feature a chamber of sufficient size to accommodate two or more cage racks or large cages. The rack washer should be placed in a pit to eliminate the need for ramps. Pits must be surfaced with rustproof grating materials, easily accessible and cleanable. Separate pits shall be designed for equipment pit(s) and drip pit(s). Grating covered drip pits must extend into the clean area to allow the clean rack to drip dry (provide separation between the dirty and clean pits). The equipment pit should be sealed, and the space around the washing equipment should be sealed to form a complete barrier between the clean and dirty sides of the cage wash area. The tunnel washer transports cages on a continuously moving conveyor through a pre-rinse, detergent wash, rinse, final freshwater rinse, and drying sequence. These units are also suited for water bottles, small cages, and other small equipment. There should be a minimum of 1.2 m (4'-0") clearance around the tunnel washer for maintenance. A common enclosed equipment service space must be provided between the clean and dirty side to provide for cage wash equipment maintenance. Noise exposure to personnel must be considered when selecting cage rack washers. An operating noise level of 85 dBa should not be exceeded.

Efficiency of water usage must be considered in planning, as this will impact the type of equipment purchased. Some water used in the rinse process may be recycled. Water may have to be treated to eliminate chemical and mineral deposits. Acid neutralization, depending on the size of the facility, may be required and should be considered during the planning phase.

There is a trend towards robotizing some or all of the cage wash functions in larger facilities. The facility has to have sufficient through put to warrant the cost of robotic equipment. Safety walls must separate the areas where people enter the robotic area from the actual equipment. Redundancy should be considered when designing a robotic cage wash facility. Consideration should be given to having one robotic cage wash line and one conventional cage wash line. Provide enough linear queuing space on both "clean" and "dirty" sides. A robotic cage wash requires a marshalling area, conveyor belts, a bedding dump station, an automated cage handler, an index tunnel washer, a cage and rack washer for larger or non standard size cages, a steam sterilizer, bedding dispenser, bottle filling station, and other

equipment associated with the robotic system. Additional robotic systems options such as dust control equipment may be considered.

All materials and finishes should be moisture resistant, sealed, and caulked. Finishes in the cage wash area should stand up to frequent high pressure water cleaning. The type of equipment used in a cage wash will require electrical source, high temperature, high volume water, and large quantities of clean steam. The HVAC requirements of the cage wash area must be carefully evaluated to ensure the safety and comfort of the personnel working in this environment.

Storage: Adequate storage space must be planned for clean cage racks, bedding and feed, any special clothing and supplies, cleaning chemicals, husbandry supplies, and procedure room supplies and equipment. Storage for chemicals and detergent drums shall be located away from heavy traffic zones. Wire mesh shelving is recommended.

Cage/Rack Repair Room/Shop: A cage/rack repair room is used primarily for large animal equipment and should be located near the large animal holding area and near the large animal cage wash entry. Equipment will be repaired and will then need to be washed. The repair shop does not have to be within the confines of the animal holding area although it is desirable to have it within the facility. Adequate electrical outlets should be provided for shop equipment. Task lighting may be required. Bench top space is required.

Feed and Bedding Storage: This area will provide space for bulk storage of feed and bedding. Calculate feed and bedding storage for the "worst case scenario" of the species that the facility may have to accommodate and protect storage space from being "squeezed out" of the facility. Storage of feed and bedding should be calculated based on a predetermined reserve supply capacity, anticipated maximum consumption per time period and maximum holding capacity of the facility.

## Summary Space Schedule for Cage Wash Functions

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Cage Wash Room | Equipment determines the size | Cage rack washer, autoclave, bedding dispenser, acid neutralizing equipment, feeder bottle filler, sink, bottle washer, and dump station. Provide a pre-wash stall. Tunnel washer may be provided in a larger animal research facility. | 3.0 (9'-0") |
| Clean Cage Storage Room | 37.72 (406) | | 3.0 (9'-0") |
| Cage Repair Shop | 21.00 (226) | Work benches, sink, welding booth w/fume hood, and gas cylinders | 3.0 (9'-0") |

| Space Name | Area M² (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Feed and Bedding Storage | 11.07 (120) | Pallets and deli refrigerator. | 3.0 (9'-0") |

## G.8 Animal Research Facility Support

Animal research facility support includes: a laundry, feed diet preparation room and cold storage for animal carcasses.

Laundry: Clean linen, either from within the facility or from a commercial laundry is distributed though the receiving office to locker rooms and gowning rooms. Based on program requirements, a laundry area may need to be provided within the animal facility. Space must also be provided to accommodate receiving clean linens if laundry is serviced outside the animal facility.

Feed/Diet Preparation Room: Many animals require special diets. The feed preparation room shall have sinks with heavy duty garbage disposal and drain boards to wash and sanitize fresh produce. Shelving and storage cabinets are also required. One or more commercial size refrigerators and freezers will be required for food storage. An icemaker may also be required. Counter tops with adequate electrical outlets should be provided for "standard kitchen" equipment such as blenders and hot plates to prepare the food.

Cold Storage for Animal Carcasses: Both the necropsy room and the loading dock require some form of cold storage to hold animal carcasses for examination and for disposal. A refrigerator is adequate for storage of small animals but a walk in cold storage room will be required for larger animals, located at the loading dock. The room should have open mesh or slat stainless steel shelves. The floor should have a drain and a lip at the door to contain any fluid spills. Separate storage facilities must be provided to house animal carcasses that contain radioactivity. These storage facilities must not have floor drains. If animal carcasses or remains contain radionuclides they are handled like other radioactive materials.

Equipment Storage: This area will provide space for shelves to store equipment.

### Summary Space Schedule Animal Research Facility Support

| Space Name | Area M² (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Laundry Room | 14.00 (150) | Commercial washer and dryer, shelves, layout table, dirty linen hamper and shelves | 3.0 (9'-0") |
| Feed/Diet Preparation Room | 7.50 (80) | Kitchen wall and base cabinets, sink, range, and refrigerator | 3.0 (9'-0") |

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Cold Room* MPW, Carcass and Waste Storage | Unit determines the size | Walk-in prefabricated unit w/ stainless steel shelves. | Unit determines the Height |
| Equipment Storage | 9.28 (100) | Shelving. | 3.0 (9'-0") |

* For large animal carcass and waste storage

## G.9 Animal Caretaker

Rooms for animal caretakers shall be provided in a transitional zone between the animal zone and the administrative areas so caretakers do not need to degown for convenience functions. Transitional areas include break rooms and gowning areas.

Break Rooms: Break rooms serve as interaction space for the animal facility staff. They should be located in the vicinity of the administration and changing areas, have a comfortable atmosphere, and be equipped with chairs, tables, bookcases, counter, microwave, ovens, refrigerator, vending machines, white boards, tack board and space for time cards if required. Trash and recycling receptacles should also be provided.

Gowning Areas: Locker, toilet, sinks and showers shall be provided for gowning prior to entering animal holding areas and for degowning after leaving the animal holding areas. Sufficient space is required for storage of protective clothing. A crossover bench or pull down seat shall be provided as well as a sanitizable display case. These rooms shall be equipped with individual full size lockers for staff. The locker must provide for the storage of clean facility scrubs and facility specific shoe storage. Space for hanging street clothing (jackets, sweaters etc) prior to gowning shall be provided. There should be a place to collect soil laundry, to plug in hair dryers, storage shelving, a mirror and lighting. Material and finishes selected shall be antimicrobial. These spaces must be designed and constructed using moisture resistant materials and wall hung fixtures to allow for ease of cleaning. If PAPRs or cartridge respirators are used in the facility, then a decon station, changing station, and storage must be provided

Locker Rooms: Locker rooms with toilets, sinks, showers, and lockers shall be provided for staff to change in and out of uniforms. These rooms require finishes identical to vivarium finishes and shall have independent circulation routes for the varied types of access required. Provide the following:

- Adequate number of lockers to meet anticipated staffing requirements, sized to provide adequate storage for personal possessions. They shall have bulkheads or sloped tops, filler panels, perforated door panels, and solid (grouted) bases.
- Benches, open storage for facility footwear, space to hang clean uniforms and space for hampers.
- Showers with vanity alcoves with small shelf and bench.
- Adequate number of toilets and sinks for anticipated staff size, complete with counter-tops, mirrors, vanity lighting, electrical for electrical receptacles for hand dryers and automatic paper towel dispensers.
- A dry vanity area including full length mirror vanity lights; shelf and electrical outlet may be considered.

Summary Space Schedule for Animal Caretaker

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Break Areas | | Vending machines, counters, tables' w/chairs, refrigerator, microwave oven with exhaust hood, drinking fountain, sink, white boards, and lounge furniture. | 2.4 (8'-0") |
| Gowning Areas w/Locker, Toilet & Shower Room | Fixtures and equipment determines the size | Water closet, shower, lavatories w/mirrors, lockers, and benches. | 2.4 (8'-0") |
| Locker Room | Fixtures and equipment determines the size. | Water closet, shower, lavatories w/mirrors, lockers, and benches. | 2.4 (8'-0") |

## G.10 Offices & Miscellaneous Space

Offices/File Rooms: Animal care is typically a contracted service at the NIH. The contractor supervisor must have at least one office that may be within the animal housing zone or the public zone. In addition, offices are required for floor/team leaders, area supervisors and trainers. Private offices should be provided for the Government management staff and veterinarians. Open office space is provided for clerical and other administrative personnel. Appropriate provision should be made for privacy. Ergonomic systems furniture should be used in all administration spaces.

Space should be provided for copying machines, FAX machines, files, shelves and other routine office equipment. In addition, space is required for central computer systems. This area does not have the stringent air change requirements that the animal holding areas have. File rooms should be located in the Animal Facility Office area. File rooms should be lockable.

Conference Rooms/Training Rooms: Conference rooms/training rooms should be provided for formal and informal meetings of staff and for periodic training. Conference areas shall be utilized on a shared basis and be designed in accordance with National Fire Protection Association (NFPA) occupant loads. Conference rooms should be equipped to accommodate flexible seating arrangements. There should be white boards, electrical connections for audio visual equipment, a screen, and adjustable overhead lighting, data and telephone lines.

Reception Area: In light of heightened security, the animal facility should have a central reception area where guests and vendors can be met and directed appropriately. The reception area should be located as close to the main entrance of the facility as possible. It should have a reception desk, chairs and low tables.

Housekeeping Closets: The animal facility must be equipped with appropriate sized housekeeping closets located throughout the facility to adequately serve its needs. A housekeeping closet must be provided with both supply air and exhaust to reduce humidity and control odors. Closets should be fitted with wire mesh shelving, mop and broom hangers, a mop sink and adequate lighting. Closets should be sized to hold cleaning supplies and equipment only. The interior of the closet must be finished with materials and surfaces that are cleanable, moisture resistant and durable.

Space Summary Office & Miscellaneous Space

| Space Name | Area $M^2$ (SF) | Equipment/Furniture and Requirements | Hgt in m (ft) |
|---|---|---|---|
| Branch Chief | 15.00 (160) | Work surfaces w/binder bins, convergent work surfaces, lateral files, tack boards, & white boards. | 2.4 (8'-0") |
| Veterinarian Office | 12.00 (130) | Work surfaces w/binder bins, convergent work surfaces, lateral files, tack boards, & white boards. | 2.4 (8'-0") |
| Secretary | 8.00 (86) | Counter, work surfaces w/binder bins & lateral files. | 2.4 (8'-0") |
| Clerical | 8.00 (86) | Work surfaces w/binder bins & lateral files. | 2.4 (8'-0") |
| Conference | 1.86 (20) | Conference table, chairs A/V equipment, white boards, etc. | 2.4 (8'-0") |
| Building Engineer's Office | 10.00 (108) | Work surfaces w/binder bins & lateral files. | 2.4 (8'-0") |
| Shipping and Receiving Office | 12.00 (130) | Work surfaces w/binder bins & lateral files, shelves for clean linen | 2.4 (8'-0") |
| Housekeeping Closets | 3.75 (40) | Mop sink and mop rack | 2.4 (8'-0") |

## H Functional Relationships and Zoning of the Animal Research Facility

The zones in an animal research facility can be grouped into four categories that are further characterized as clean or dirty. Clean or dirty refers to the potential for the animal or material to transmit diseases to other animals from outside sources. For example, animals from an unapproved source are considered "dirty" until they have been evaluated for health status during a quarantine period. Barriers within the facility are "clean" and should only receive "clean" approved animals and materials; whereas used cages are "dirty" and should not move into designated "clean" areas because they may be a source of contamination.

## H.1 Public Zones:

Public zones include public corridors and elevators, multiuse loading docks, supply rooms, laboratories outside of barrier areas, and areas where staff wear street clothes. Public zones are categorized as "dirty" because there is no control of potential animal contaminants in these areas.

## H.2 Transitional Zones:

Transition zones are defined as areas of movement between public areas and animal holding and procedure areas or between zones housing different animal species that could potentially transmit diseases between each other if they were in close contact. Transitional zones may include airlocks, gowning areas, locker rooms, feed and storage areas, and dedicated "clean" and "dirty" animal elevators.

## H.3 Specific Pathogen Free (SPF) Zones:

SPF zones refer to areas where animals are free of defined diseases. The degree of SPF may vary in different parts of the facility just as the degree of "clean" and "dirty" may vary. The level of SPF and "clean"/"dirty" will be defined by the veterinarians and the users of the facility. Most housing/holding areas are located in the SPF zone. An exception to this occurs when "dirty" animals (non defined disease status) are needed for the research. A separate housing area that contains isolation housing and/or has an airlock shall be provided for this purpose.

## H.4 Contaminated Zones:

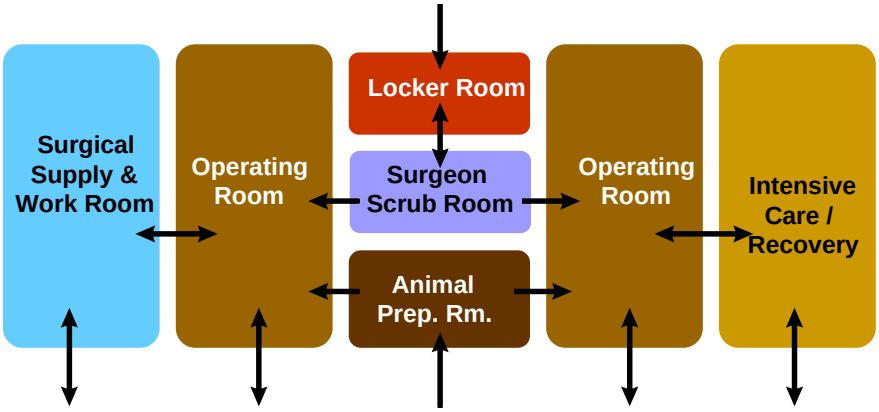
Contaminated zones are areas where dead or infected/diseased animals are located or where "dirty" equipment is transported or stored. There are instances where conventional housing is required for "dirty" animals such as a quarantine room or an area of the facility specifically for research using "dirty" (non SPF) animals. Circulation routes must be closely examined in these situations so as to minimize cross contamination of SPF animals. Physical barriers and air pressure relationships shall be designed to minimize cross contamination.

"Dirty" corridors are those used for moving soiled cages and materials to the "dirty" side of the cage wash facility. Rooms where necropsies or perfusions (terminal procedures) are performed are defined as "dirty". A single corridor system can be managed so as to provide the desired degree of cleanliness and species separation defined by the facility program.

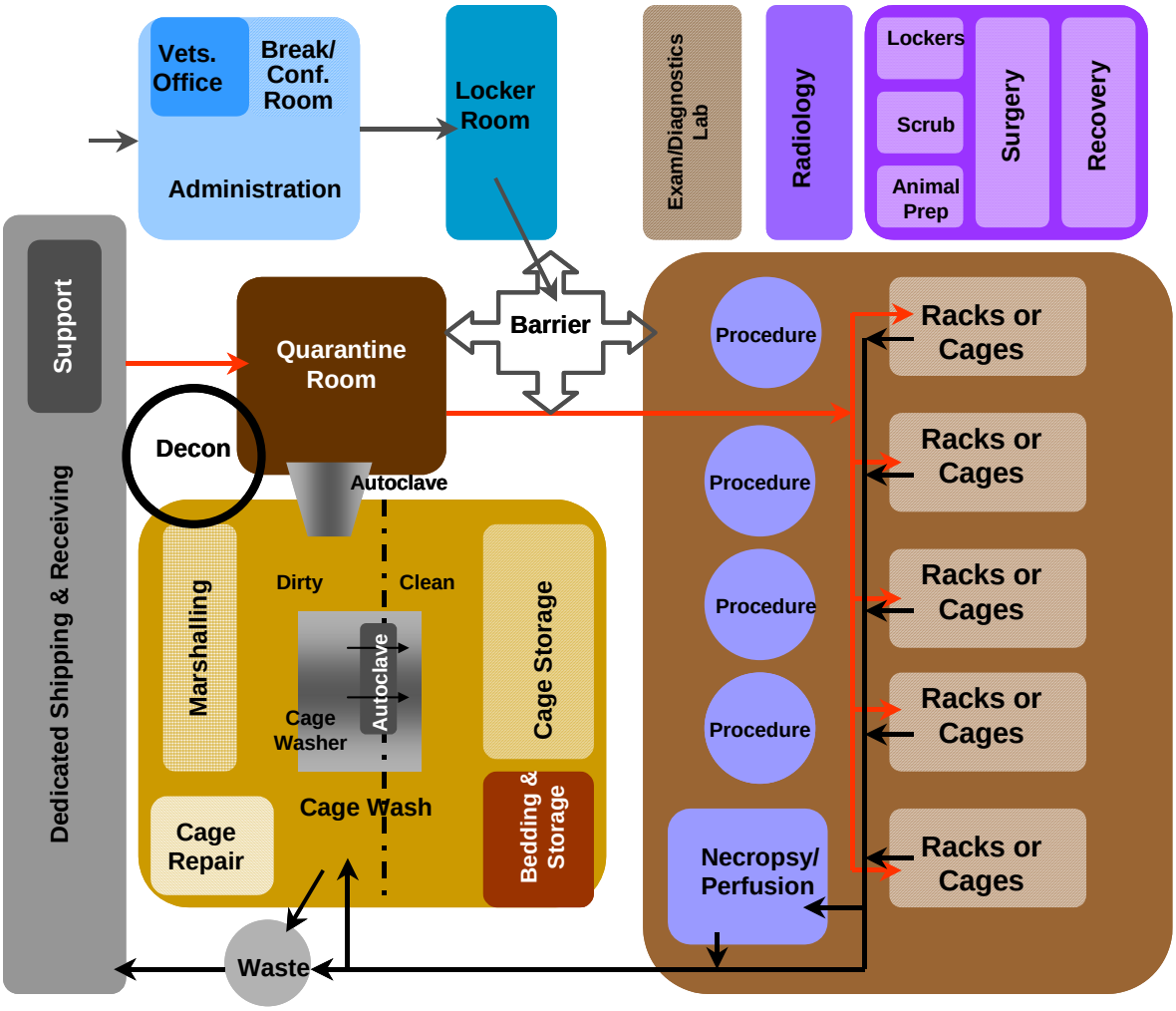
## H.5 Zone Relationships:

Early in the planning process, the Project Officer and the Programmer should work with the facility representatives to prepare a POR that includes functional and adjacencies flow charts that will facilitate the design process. In addition to impacting the ease of doing animal model based science, the arrangement of critical adjacencies will greatly impact the quality of life of the animals, the caretakers, and the veterinarians. Appropriate adjacency planning shall mitigate interference from noise and vibrations, economize circulation routes, and maintain the appropriate degree of cleanliness of the facility.

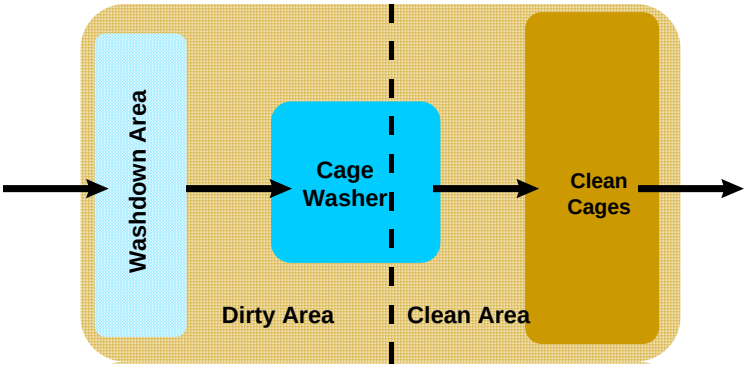
Within the animal research facility and the loading dock, the flow of materials, cages, animals, and personnel shall be accommodated in an efficient and economical manner. Adjacencies shall be planned to maximize operational efficiencies, minimize travel distances and maintain zonal relationships. It is also essential that designs consider adjacencies based upon the variety of species that are anticipated for the animal research facility.




**Surgery Suite Functional Relationship Diagram**




Vivarium Functional Relationship Diagram




Cage Wash Functional Relationship Diagram

## H.6 Circulation of People, Animals and Materials

Circulation space is a critical factor in controlling contaminants and enhancing operations and procedures within the animal research facility. Planning of circulation focuses on the movement of cages and racks in the facility. Most importantly, during the planning, phase the design team decides the extent to which the corridor system helps manage the potential for contamination and to what extent management dictates certain protocols of time and direction of movement. Personnel, equipment and supplies should move from areas of least contamination to areas of greater contamination. Movement of personnel, equipment and supplies should be planned to minimize the potential for contamination of cleaner areas. Consideration should be given to the equipment and areas required to permit circulation of supplies, personnel and equipment. For example, autoclaves located near the dirty cage wash permits the circulation of contaminated caging back into the cage wash area. Convenient location of locker rooms and shower facilities in many cases permits personnel to move from dirtier areas back into cleaner situations. Consideration should be given to directional airflow and odor control.

## H.7 Corridors:

Commonly accepted circulation systems include a single corridor, a dual clean and dirty corridor, or a single corridor with unidirectional flow.

Single Corridor System: In single corridor scheme traffic flow is in both directions between the animal holding room and the cage wash area. The most significant advantage of a single corridor system is its efficiency of space utilization. The disadvantage is the potential for cross contamination in the corridor when clean and soiled cages share space. Congestion caused by moving animals, cages, and supplies through a single corridor is also problematic. Contact between clean and dirty materials can be minimized by carefully scheduling pickups and deliveries, covering cages when moving them, and by using a unidirectional circulation system. With this management technique, congestion and contamination can be minimized. Single corridor systems shall be equipped with appropriately placed air locks and doors to maintain the desired level of facility air pressurization relationships, a level animal sanitation and security. Placement of airlocks must be discussed with users. Doors should be powered operated should have controlled access where necessary.

Dual Corridor System: Contamination control is the primary rational for choosing a dual corridor system. The dual corridor system has animal holding rooms leading to two separate corridors that are dedicated clean and dirty corridors for the movement of cages. The flow of cages is unidirectional and may involve two single loaded corridors in a small facility, one double loaded and two single loaded corridors in a larger facility. Dual corridors are not an efficient use of space and will increase the gross to net ratio.

Corridor Width: Corridor width should be dependent on the flow of traffic within the animal facility and the amount of storage that will be available in or near the facility. The Guide recommends a corridor width of 1 825 mm (6'-0") – 2 450 mm (8'-0") but 3 050 mm (10'-0") - 3 650 mm (12'-0") wide corridors allow for more flexibility in circulation in larger facilities. Two animal cage racks or pieces of the largest mobile equipment must be able to pass each other without restriction in the corridor. Sufficient storage must be designed in or near the facility so that equipment does not have to be stored in the corridors. Marshalling alcoves for racks and carts should be provided so that corridors are kept free of this equipment. The corridor corners should be rounded. Wall and corners shall have physical protection.

## H.8 Vertical Circulation-Elevators:

In multilevel facilities, dedicated clean and dirty animal elevators are required. The elevator for transporting clean material should be located near the clean side of the cage wash area, while the elevator used for soiled material should be in close proximity to the soiled side of the cage wash area. The elevator size and location must accommodate the volume of materials to be handled in the cage wash, animal and material receiving, and waste removal areas. Elevators that will be used for transport of animals and animal facility equipment must be constructed of highly durable and cleanable materials. The elevator cab floor material must be of the same material as the floor in the animal facility. The elevator car interior should have guardrails at appropriate heights for the typical racks and carts that will be used in the facility. Elevator doors must be of sufficient height to accommodate the tallest racks that will be used in the facility. Consideration should be given to an elevator door width that can accommodate at least two racks side by side.

At least one elevator should have the capacity to handle extremely heavy loads if, for instance, an irradiator is planned in the facility on a level below the loading dock level of the building. There should be adequate redundancy in the number of elevators to handle freight, staff and animals in the case of an equipment breakdown.

## H.9 Security

The objective of security in an animal research facility is to ensure the safety of the animals, staff, equipment, and data. At NIH owned or leased facilities; the site is the first level of security. The site may be open to the public or it may have controlled access depending on the location. The second level of security is the building. Access to the building must be managed. Air intakes and any central utilities must be safeguarded from intruders. The third level of security is the access to the animal research facility. Administrative staff, research and veterinary staff, maintenance staff and vendors will require access to the animal research facility. A controlled point of entry is required prior to entering the vivarium. Security features must also be provided for the loading docks and service entries for the animal fa-

cility. Finally, the fourth level of security is the specific animal rooms, containment suites, surgical suites, pharmacy, or other areas within the animal facility with a higher level of controlled access and surveillance. Design an internal facility system to limit/control access to animal holding rooms and other areas. The A/E shall coordinate security requirements with DPSM.

## H.10 Vivarium Loading Docks

Refer to Section 3-3-10-C: Loading Docks, Delivery and Service Areas: The loading dock that services a building with an animal facility should include a dedicated bay for animal and material receiving and waste removal. The animal care loading dock must be viewed as an extension of the animal care facility. Excluding pests and creating conditions that promote proper sanitation, at this location, are imperative to maintaining a pest free facility that meets or exceeds AAALAC Guidelines. To achieve these desired goals of pest exclusion and good sanitation, the dock facility must be: properly sited, constructed of durable; cleanable materials; sized to meet current and future program needs; allow for some flexibility in use; and create an effective barrier between the outside and the clean environment of the animal care facility. The animal receiving loading dock should include:

- A dedicated animal facility bay that is visually protected for security. The dock must be physically segregated form other dock space and dock functions. This includes vehicle docking and material/supplies staging space.
- A receiving vestibule that is temperature and humidity controlled to protect valuable research animals. Overhead doors should be fitted with proper sweeps, gaskets, and brushes to exclude insects and rodent pests around the perimeter of the entire door. These doors and doorframes must provide an effective seal, when closed, to exclude insect and rodent pests. The loading dock doors should be equipped with air curtains or other similar devices to exclude flying insects and to create a dust and dirt barrier when the receiving or personnel doors are opened.
- A dedicated route of transportation into the animal facility if possible
- A large pass through autoclave if bedding is to be sterilized at the loading dock
- An area to decontaminate the animal containers before they enter the animal facility. The decontamination area can be at the loading dock or at the point of entry to the animal facility. The interior surfaces should be covered with materials that facilitate proper sanitation and ease of cleaning as is necessary in an animal care facility. These materials must be durable enough to withstand regular cleaning and disinfection. Facilities must be available for loading dock wash down and cleanup. Floor drains should not be designed into the receiving area of the loading dock.
- A cold storage room for animal carcasses.

- The dock entry points, e.g., materials receiving or personnel must be isolated from solid waste compacting, handling and storage operations. Solid waste operation can be attractive to pest species that are invasive to the facility.
- Recycling containers should not be sited on or near an animal facility loading dock. Waste should not be staged for removal inside the receiving area of the loading dock.
- There should be no exposed conduit, piping, ledges, wall mounted lights, etc. These provide perching and nesting sites for nuisance birds and are difficult to clean.
- Wall, corner and door guards should be of a type used inside the animal care facility, i.e., stainless steel, caulked and sealed at installation.
- An animal receiving room.
- Electrical service should be provided on all walls of the receiving area and the elevator lobby to power electric light traps for pest exclusion.
- Empty conduit and back box system for an audio visual communication device at the animal receiving area with a minimum of two remote points within the vivarium.
- Electric pest control devices.
- Lighting should be indirect to the loading dock to reduce attraction of flying insects. Do not use wall mounted lighting. Do not install lights directly above receiving or personnel doors.
- Provide a dedicated animal loading dock manager's office
- Bulk chemical storage
- Gas cylinder storage

If animal bedding exits the building via a chute system, the loading dock configuration shall accommodate a front end container. Provide a container (compactor or dumpster) with an ability to be connected by a chute. On the "dirty" side of the loading dock, provide a concrete pad and guardrails matching up to the dumpsters, and provide a water source 10 meters away from the loading dock. Space shall be provided for a dedicated compactor for vacuum bedding disposal system.

## 2-4-30 Design Document Requirements

### A. Program of Requirements

Project Officers are encouraged to use the information in this Section to prepare PORs for NIH animal research facilities. A POR for the specific project shall be developed in accordance with Volume I Section 2-5 of the HHS Facilities Program Manual. In addition the programming process shall address user needs, population density, building circulation, mechanical, electrical, and plumbing systems, and all aspects of safety.

## B. NIH Facility Budget Estimates

NIH Planners and Project Officers are encouraged to use the information in this section to prepare budget estimates for NIH animal research facility.

## C. HHS Facility Project Approval Agreements

Project Officers are encouraged to use the information in this section to prepare FPAAs for NIH animal research facility facilities.

## D. Project Definition Rating Index

Project Officers are encouraged to use the information in this Section to enhance their PDRI scores.

## E. Vivarium Concept Design

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this section as a reference in developing their conceptual design for their NIH animal research facility project.

## E.1 Outline Specifications

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this Section as a reference in developing their outline specifications for their NIH animal research facility project.

## E.2 Square Meter or Broad Order of Magnitude Cost Estimate

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this Section as a reference in developing their broad order of magnitude cost estimate for their NIH animal research facility project.

# Section 2-5: Containment Laboratories at BSL3 Level



## 2-5-00 Design Requirements

The purpose of this section is to develop NIH Programs of Requirements (POR), concept or schematic designs and other planning and programming documents and shall be used for design review for compliance of Section 2-5-00 “Design Requirements” in the concept or schematic design.

“Containment” means safe methods for managing infectious materials in the laboratory environment where they are being handled or maintained. The purpose of containment is to reduce or eliminate potential exposure of laboratory workers, other persons and the outside environment to potentially hazardous agents.

Principals of Biosafety: The principals of biosafety as outlined by the latest edition of BMBL describe two models for laboratory containment. Primary containment barriers for the manipulation of infectious materials are the Biological Safety Cabinet (BSC) or other physical containment device approved by the NIH. Secondary containment barriers are the walls, floor and ceiling of the laboratory. The secondary containment barrier is constructed in a manner that prevents microorganisms from being disseminated into the environment outside the BSL3 lab. Inward directional airflow and room pressurization gradient must be maintained at all times to ensure that any aerosolization of biological material is contained within the secondary containment barrier of the laboratory.

Laboratory practice and technique requirements will be defined by the NIH Division of Occupational Health and Safety (DOHS). References to safe practice in a lab setting are also discussed in the BMBL and other industry standard publications.

### A. Facility Design and Construction

The design and construction of the facility contributes the laboratory worker’s protection, provides a barrier to protect persons outside the laboratory, and protects persons or animals in the community from infectious agents which may accidentally release from the laboratory. When the risk of infection by exposure to an infectious aerosol is present, higher levels of

primary containment and multiple secondary barriers may become necessary to prevent infectious agent from escaping into the environment. Such design features include specialized ventilation system to ensure directional air flow; room pressurization gradient; air treatment system to decontaminate or remove agents from exhaust air; control access zones; airlocks as laboratory entrance; or separate buildings or modules to isolate the laboratory.

A BSL3 environment shall have:

- Controlled access
- Physical separation from access corridor
- Anteroom; two self closing interlocked doors in series
- Single pass air directional airflow
- Air pressure differential (-12.5 Pa or -0.05" w.g. at each barrier door and lab
- An exhaust system independent and separate from the remainder of the building
- A supply system independent and separate from the remainder of the building
- Single HEPA filtered exhaust
- Supply/exhaust fan interlock
- Redundant exhaust fans required (N+1)
- Utilities backflow prevention
- 6 air changes per hour minimum
- Personnel shower
- Autoclaves available in facility
- Sealed windows.
- Sealed penetrations (including raceway) visible for inspection and maintenance
- Seamless floors
- Monolithic ceiling
- Chemical resistant finishes; floors, walls, ceilings, doors and frames, piping, fixtures and casework
- BSL3 lab on emergency power
- HVAC failure alarm
- Pressure differential monitors
- Deep seal traps
- Hands free hand washing sink with eyewash
- Surface mounted sealed lighting
- Pendent sprinkler heads
- Less than NC 45 noise level
- Compliance with NIH Biosafety Level 3 – Laboratory Certification Requirements.

## B. Project Management:

The management of a NIH project dealing with BSL3 laboratories begins with the understanding of the principals of biosafety and biocontainment. Communication of these understandings to the NIH organization should be considered and measured against the collective knowledge of the NIH organization. A thorough understanding of industry standards, guidelines and the planning principals outlined in the following chapter is also necessary for the execution of a successful project Risk assessment for the facility will be required to determine or identify the operational protocols that will need to be developed in conjunction with the design.

## C. BSL3 Access Control:

Access to the laboratory shall be limited as per the NIH security and safety guidelines. The A/E shall coordinate requirements with DPSM and DOHS. See Chapter 7. Building Automation Systems for additional information on access control

## D. Personal Protective Equipment:

Personal Protection Equipment (PPE) requirements shall be evaluated in the pre-design phase. User evaluation of PPE shall be a precursor to the program phase. Scientific program needs will determine the agent types and the PPE required for handling these agents. Information provided by the owner group will be sorted into categories:

- Issues to consider
- Best practices
- Absolute requirements
- Conditional requirements

PPE requirements shall be determined by facility protocols as developed by the scientific program. Protocols may have a space impact, and planning considerations for the storage of “clean” and “dirty” PPE.

## E Security Performance Criteria:

Biosecurity and physical security are both important features that will have an impact on the final design solution. The A/E shall consult with DOHS for the facility requirements and DPSM for all related design criteria, as well as for specific information on the standards for physical security.

Biosecurity requirements for BSL3 laboratories reside with the DOHS. The CDC select agent act outlines the requirements for safeguarding select agents. Care shall be taken in the coordination of access control and door hardware at the points of entry to the containment zones or labs.

### F. Cost Analysis:

Cost analysis at each milestone of the project shall be prepared. Benchmarking analysis of like facilities is recommended. Escalation in cost over time is a factor that shall be considered. It is important to incorporate known technologies and materials, and allow standard construction methods, thus eliminating many unknowns in the final analysis.

## 2-5-10 Design Guidance

### A. Laboratory Activities

Where work is done with indigenous or exotic agents with potential for respiratory transmission that may cause serious and potentially lethal infection (e.g. mycobacterium tuberculosis, St. Louis encephalitis virus, etc.) are anticipated to be used, then a BLS3 laboratory should be provided.

At BSL 3, more emphasis is placed on primary and secondary barriers to protect personnel outside containment areas, the community, and the environment from exposure to potentially infectious agents. Secondary barriers for this level include controlled access to the laboratory. Ventilation methods that minimize the release of infectious agents from the laboratory are required in the event of a spill.

### B. BSL3 Laboratory Design Considerations

Biosafety level 3 (BSL3) is classified as a “contained” space. The National Institutes of Health relies on the BMBL for classification and guidance in the use of category B agents used at BSL3 and DPSM, SER, DOHS, ORS at the NIH, and also the Code of Federal Regulation, Title 42 Part 73 *Possession, Use and Transfer of Select Agents and Toxins*, Title 7 Part 331 and Title 9 Part 121. These agents have the potential to become airborne and can cause serious risk to health. This section will discuss three types of spaces that will be operated as “BSL3”.

A BSL3 environment shall have single pass air independent and separate supply and exhaust air systems, directional airflow, room pressurization gradient, normal drain system, 6 air changes per hour (minimum) driven by heat load and/or local exhaust, supply/exhaust interlock, exhaust HEPA filtered, air pressure differential, self closing/locking doors, hands free hand wash sink with eyewash, seamless floors with integral cove bases, monolithic ceiling, supply, two doors in series, 50 L/s doorway infiltration, personnel shower optional, capable of being sealed, and an autoclave available in the facility. The BSL3 physical environment shall have controlled access.

In BSL3 laboratories all procedures involving the manipulation of infectious materials must be conducted within a BSC (preferably Class II or Class III), or other physical containment devices. In addition, safety and operational protocols including respiratory and personal protective equipment (PPE) use are dependent upon the scientific program requirements.

The BLS3 lab environment is the secondary containment barrier. A BSL3 lab shall have a physical separation from the access corridors by way of a vestibule or airlock with self closing doors. Negative airflow into the laboratory shall the method for containment of airborne BSL3 agents within the lab. The exhaust air shall not be recirculated, and all waste shall be decontaminated.

## C. Space Descriptions

BSL3 Laboratory: The design features of a BSL3 laboratory shall ensure containment of infectious agents used at BSL3. This BSL3 containment barrier shall be constructed to meet the requirements of the "NIH Biosafety Level 3 – Laboratory Certification Requirements." The primary method of containment within the BSL3 laboratory environment is directional air flow. The BSL3 laboratory shall be negative to adjacent spaces of a lesser biosafety level. The concept and criteria for directional air flow is discussed in Chapter 6 HVAC.

The BSL3 laboratory shall be designed to provide maximum containment of aerosolized infectious agents used in scientific research programs. Due to the dangerous nature of such studies, aerosolization shall occur inside of the BSC, to ensure maximum protection of personnel and the surrounding environment.

The level of personal protective equipment shall be determined by program and associated protocols set by DOHS. The secondary containment barrier is the walls, floor and ceiling of the BSL3 cabinet laboratory and shall meet the criteria of a BSL3 laboratory as outlined in Section 4-7 "BSL3 & ABSL3 Biocontainment." The primary method for containment for the laboratory environment is provided by directional air flow

BSL3 Support Spaces: Laboratory support spaces with a BSL3 laboratory equipped with Class II or III BSCs shall have the same physical requirements as the BSL3 area they support.

Anterooms: BSL3 environments shall have a ventilated anteroom to provide separation from areas with unrestricted traffic flow. This passage shall be arranged with two sets of self-closing doors. The anteroom doors shall be interlocked to prevent simultaneous opening of doors between the outside corridor and containment areas. Entrance interlocks, when present, shall be provided with a manual override for use in case of emergency. A

visual indicating device is required to verify directional airflow. Final determination on the design of airlocks for these facilities shall be made in consultation with DOHS personnel.

Showers: Showers shall be designed utilizing a pass through arrangement. Design requirements for showers serving BSL3 laboratories are determined based on program need and facility protocols. In addition to the requirements of the BMBL and DRM requirements, the number of showers, arrangements, and sizes shall be based on thru-put analysis.

## D. Mechanical, Plumbing and Electrical Services

Separate and independent supply and exhaust systems are provided. Exhaust air is HEPA filtered. The amount of contaminated ductwork should be minimized.

Utilities: Lab services, including hot and cold water, $CO_2$ gas, and liquid nitrogen are surface mounted. Spare capacity is recommended. BSL3 utilities shall be sealed to the BSL3 containment barrier and shall be constructed to meet NIH Biosafety Level 3 – Laboratory Certification Requirements.

- Service penetrations shall have backflow prevention.
- The HVAC exhaust shall have single HEPA filtration as discussed in Chapter 6 HVAC.
- Specific laboratory gases vary in each case and are dependant upon scientific program.
- Central vacuum is typically not recommended.
- Exposed conduit, piping or pathways are to be resistant to decontamination chemicals and easily cleaned behind, if surface mounted.

Electrical service to the area is from a redundant electrical system backed by standby generators. Electrical and data outlets are integral to the containment barrier. Conductors for power data or any other system are sealed so that the penetration meets the criteria of the room-tightness integrity testing.

BSL3 Lighting: Lighting shall be surface mounted with a single penetration for each fixture. Light fixture housing shall be of a material or finish that resists the corrosiveness of decontamination chemicals; shall be smooth for wipe down and to prevent the snagging or tearing of protective gloves. Fixtures shall be sealed to the ceiling or wall to prevent harborage of pests or vermin.

## D.1 Directional Airflow:

BSL3 laboratories rely on directional airflow and room pressure gradients as a primary means of containment. Air pressure balance is maintained by the mechanical and control systems to maintain pressure differentials at each barrier door.

Inward Airflow: Biocontainment laboratories will be divided into zones that demark the level of containment required. The deepest negative pressure would be maintained in the zone that is considered the highest level of contamination risk. The mechanical and control section will discuss the pressure differentials required for each zone, and the methods for monitoring and maintaining pressures within each zone.

Outside Air Infiltration Control: Air infiltration from the containment wall can have an effect on the air balance of the interior rooms in a facility. For that purpose, it is recommended that the containment wall be designed to minimize the amount of air infiltration into a zone containing BSL3 laboratories and animal facilities. Consider the need for a buffer zone between the containment facility and the outside wall.

### D.2 Decontamination

Solid waste shall be decontaminated by use of an autoclave. Autoclaves with a double door pass through function are preferable, but single door autoclaves are acceptable. Liquid waste shall be decontaminated in the laboratory through scientific protocol. Liquid decontamination systems can be utilized with the approval of DOHS and are not typically required or desired. The scientific program along with DOHS shall be required to verify the decontamination methods and types of chemicals used in the facility. The A/E shall evaluate the building systems for compatibility. Rooms shall be capable of being sealed for protocols that require gaseous decontamination in accordance with NIH Biosafety Level 3 – Laboratory Certification Requirements.

Decontamination systems are discussed elsewhere in the DRM and include items such as pass through devices, decontamination equipment, carcass disposal, liquid decontamination and other methodologies used in the containment environment.

## 2-5-20 Design Information

### A. General Staffing Patterns of an NIH Containment Laboratory

A containment laboratory may not be permanently staffed. At the Centers for Disease Control and Prevention (CDC) there are containment laboratories that are on standby to address a national healthcare emergency.

# 2-5-30 Design Document Requirements

## A. Program of Requirements

Project Officers are encouraged to use the information in this Section to prepare PORs for NIH containment laboratories. A POR for the specific project shall be developed in accordance with Volume I Section 2-5 of the HHS Facilities Program Manual. In addition the programming process shall address user needs, population density, building circulation, mechanical, electrical, and plumbing systems, and all aspects of safety.

## B. NIH Facility Budget Estimates

NIH Planners and Project Officers are encouraged to use the information in this section to prepare budget estimates for NIH animal research facility.

## C. HHS Facility Project Approval Agreements

Project Officers are encouraged to use the information in this section to prepare FPAAs for NIH animal research facility facilities.

## D. Project Definition Rating Index

Project Officers are encouraged to use the information in this section to enhance their PDRI scores.

## E. Laboratory Concept Design

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this section as a reference in developing their conceptual design for their NIH animal research facility project.

## E.1 Outline Specifications

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this section as a reference in developing their outline specifications for their NIH animal research facility project.

## E.2 Square Foot or Broad Order of Magnitude Cost Estimate

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this section as a reference in developing their broad order of magnitude cost estimate for their NIH animal research facility project.

# F. Special Requirements:

## F.1 Risk Assessment:

A risk assessment shall be performed to determine the level of threat to the local environment, as directed by DPSM.

## F.2 Protocol Development:

Building operations and maintenance protocols shall be developed in conjunction with the design and engineering of the facility. Scheduled maintenance of the building containment components and systems shall to be developed. The following shall be considered:

- Duration of the scientific program
- Standard protocols for maintaining the lab during shut down periods
- Location of equipment inside and outside of containment
- In situ decontamination of lab components (i.e., HEPA filters)
- Monitoring of all life safety systems.

## F.3 BSL3 Pre-Testing, Commissioning and Certification:

The A/E shall reference the most current versions of the following documents listed as NIH acceptance criteria for pre-testing, commissioning and certifications. Testing criteria for a BSL3 is as follows:

- BSC Certification – NSF Standard 49
- All HEPA filters shall be tested using IEST-RP-CC001.3 or an APPROVED equivalent test procedure. Poly-Alpha Olefin (PAO) shall be used in lieu of Di-Octyl Phthalate (DOP) as a traces gas.
- Liquid decontamination system (if installed) Biological Challenge Test requirements
- NIH Biosafety Level 3 Laboratory Certification Requirements
- Autoclave testing and Biological Challenge Test criteria
- Chemical resistance criteria of materials
- Pre-testing of all building services and components serving the containment areas (e.g. HVAC, power distribution, BAS).

## F.4 Containment Barrier Validation:

To receive commissioning approval, surfaces shall meet the following criteria:

- Uniformity of texture
- Smooth surface finish
- Acceptable hardness
- A minimum number of symmetrically spaced form seams
- All pit and pinholes are to be filled
- All projections shall be removed to a level flush with the surface

- Corners and surfaces shall be plumb and square
- Porous or defective substrates shall be repaired
- Patching shall be done using only a manufacturer's approved high performance coating bonding agent and crack filler.

# Section 2-6: Containment Vivariums @ ABSL3 Level



## 2-6-00 Design Requirements

The purpose of this section is to develop NIH Programs of Requirements (POR), concept or schematic designs and other planning and programming documents and shall be used for design review for compliance of Section 2-6-00 “Design Requirements” in the concept or schematic design.

The ABSL3 facility is designed to house animals infected with potentially lethal disease for the purpose of research at Biosafety Level 3. An ABSL3 facility is a biocontainment facility. The purpose of containment is to reduce or eliminate exposure to veterinarians, animal care workers, other persons and the outside environment to potentially hazardous agents. Principals of Biosafety: The principals of biosafety as outlined by the latest edition of BMBL describe two models for vivarium containment; they are primary and secondary.

The primary containment barrier in an animal facility is the animal isolators. Isolators rely on directional airflow and room pressurization gradient as the primary containment concept. The ABSL3 room is an extension of the primary containment and is the barrier of containment utilizing the directional airflow concept and room pressurization gradient. The concept and criteria for directional air flow and room pressurization gradient is discussed in Chapter 6 HVAC. Animal studies that use open caging, create an environment within an ABSL3 facility that poses the greatest risk to human health. DOHS shall be consulted on issues of safety protocols when ABSL3 facilities are planned.

Consideration should be given to use of restraint devices and practices that reduce the risk of exposure during animal manipulation (e.g., physical restraint devices, chemical restraint medications etc). Infected animals should be housed in containment caging systems (such as solid wall and bottom cages covered with filter bonnets, open cages placed in inward flow ventilated enclosures, HEPA filter isolators and caging systems, or other equivalent primary containment systems) to reduce the risk of exposure to infectious aerosol from infected animals and bedding. Primary containment caging systems must be able to be decontaminated and HEPA filtration systems leak tested. Actively ventilated caging systems must be design to prevent the escape of microorganisms from the cage. Exhaust plenums

for those systems shall be sealed to prevent escape of microorganisms if the ventilation system becomes static, and the exhaust must be HEPA filtered. Safety mechanisms shall be in place that prevent the cages and exhaust plenums from becoming positive to the surrounding area should the exhaust fan fail. The system shall be alarmed to indicate when operational malfunctions occur.[1]

Secondary containment barriers are the walls, floor & ceiling of the vivarium. The secondary containment barrier is constructed in a manner that prevents microorganisms from being disseminated into the environment. Inward directional airflow and room pressurization gradient must be maintained at all times to ensure that any aerosolization of biological material is contained within the secondary containment barrier, the vivarium. External windows are not recommended; if present, all windows must be sealed and resistant to breakage.

Vivarium practice and technique requirements will be defined by the NIH Division of Occupational Health and Safety (DOHS). References to safe practice in a vivarium setting are also discussed in the BMBL and other industry standard publications.

## A. Facility Design and Construction

The design and construction of the facility contributes to the animal care worker's protection, provides a barrier to protect persons outside the laboratory, and protects persons or animals in the community from infectious agents which may be accidentally released from the laboratory. When the risk of infection by exposure to an infectious aerosol is present, higher levels of primary containment and multiple secondary barriers may become necessary to prevent infectious agents from escaping into the environment. Such design features include specialized ventilation systems to ensure directional air flow, room pressurization gradient, air treatment system to decontaminate or remove agents from exhaust air, control access zones, airlocks at entrances, or separate buildings or modules to isolate the vivarium.

An ABSL3 environment shall have:

- Controlled access
- Physical separation from access corridor
- Anteroom; two self closing interlocking doors in series
- Single pass air and directional airflow
- Air pressure differential
- Pressure differential monitors
- An exhaust system independent and separate from the remainder of the building
- A supply system independent and separate from the remainder of the building

[1] 5th Edition of BMBL

- Single HEPA filtered exhaust
- Supply/exhaust fan interlock
- Redundant exhaust and supply fans required (N+1)
- Utilities require backflow prevention
- 10 air changes per hour minimum
- Personnel shower (need based on agents used)
- Pass through autoclaves available in facility
- No windows
- Sealed penetrations visible for inspection and maintenance
- Seamless floors with integral cove base
- Monolithic ceiling
- Chemical resistant finishes; floors, walls, ceilings, doors and frames, piping, fixtures and casework
- Emergency power
- Hands free operated hand wash sink located at the exit of the animal room or animal suites, necropsy/procedure room and similar locations
- Deep seal traps
- Surface mounted sealed lighting
- Pendent sprinkler heads.
- Visual indication of directional airflow
- HVAC failure alarm
- Sealed, break resistant door vision panels
- Cage wash access
- Compliance with NIH Biosafety Level 3 – Laboratory Certification Requirements.

All utility penetrations shall be constructed to meet NIH Biosafety Level 3 – Laboratory Certification Requirements. Also, refer to Chapter 8 Plumbing, Chapter 6 HVAC, and Chapter 10 Electrical for utility requirements.

## B. Project Management:

The management of a NIH project dealing with ABSL3 vivariums begins with the understanding of the principals of biosafety and biocontainment. Communication of these understandings to the NIH organization should be considered and measured against the collective knowledge of the NIH organization. A thorough understanding of industry standards, guidelines and the planning principals outlined in the following chapter is also necessary for the execution of a successful project Risk assessment for the facility will be required to determine or identify the operational protocols that will need to be developed in conjunction with the design.

## C. ABSL3 Access Control:

Access to the vivarium shall be limited as per the NIH security and safety guidelines. The vivarium is separated from areas that are open to unrestricted personnel traffic within the building. External facility doors are self closing and self locking operated under “fail secured protocol. Doors to areas where infectious materials and/or animals are housed open inward, are self closing, and are kept closed when experimental animal are present. Entry into the containment area is via a double door entry which constitutes an anteroom and a change room. An additional double door access anteroom or double door autoclave may be provided for movement of supplies and waste into and out of the facility. The A/E shall coordinate requirements with DPSM and DOHS. See Chapter 7 Building Automation Systems for additional information on access control

## D. Personal Protective Equipment:

Personal protective equipment (PPE) requirements shall be evaluated in the pre-design phase. User evaluation of PPE shall be a precursor to the program phase. Scientific program needs will determine the agent types and the PPE required for handling these agents. Information provided by the owner group will be sorted into categories:

- Issues to consider
- Best practices
- Absolute requirements
- Conditional requirements

PPE requirements shall be determined by facility protocols as developed by the scientific program. Protocols may have a space impact, on planning considerations for the storage of “clean” and “dirty” PPE

## E Security Performance Criteria:

Biosecurity and physical security are both important features that will have an impact on the final design solution. The A/E shall consult with DOHS for the facility requirements and DPSM for all related design criteria, as well as for specific information on the standards for physical security.

Biosecurity requirements of ABSL3 laboratories reside with the DOHS. The CDC select agent act outlines the requirements for safeguarding select agents. Care shall be taken in the coordination of access control CCTV monitoring and door hardware at the points of entry to the containment zones or vivariums.

### F. Cost Analysis:

Cost analysis at each milestone of the project shall be prepared. Benchmark analysis of like facilities is recommended. Escalation in cost over time is a factor that shall be considered. It is important to incorporate known technologies and materials, and allow standard construction methods, thus eliminating many unknowns in the final analysis.

## 2-6-10 Design Guidance

### A. Vivarium Activities

Where work is done with indigenous or exotic agents with potential for respiratory transmission that may cause serious and potentially lethal infection (e.g. mycobacterium tuberculosis, St. Louis encephalitis virus, etc.) then an ABSL3 vivarium must be provided.

At ABSL3, more emphasis is placed on primary and secondary barriers to protect personnel in contagious areas, the community, and the environment from exposure to potentially infectious aerosols. Secondary barriers for this level include control access to the vivarium and ventilation requirements that minimize the release of infectious aerosols from the facility.

### B. ABSL3 Laboratory Design Considerations

Animal Biosafety Level 3 (ABSL3) is classified as a “contained” space. The National Institutes of Health relies on the BMBL for classification and guidance in the use of category B agents used at BSL3 and DPSM, SER, DOHS, ORS at the NIH, and also the Code of Federal Regulation, Title 42 Part 73 Possession, Use and Transfer of Select Agents and Toxins, Title 7 Part 331 and Title 9 Part 121. These “indigenous or exotic agents” have the potential to become airborne and can cause serious risk to health. This section will discuss three types of spaces that will be operated at “ABSL3”.

An ABSL3 environment shall have single pass air, Separate and independent supply and exhaust air systems, directional airflow, room pressurization gradient, normal drain system, 10 air changes per hour (minimum) driven by heat load and/or local exhaust, supply/exhaust interlock, exhaust shall be HEPA filtered, air pressure differential monitors, self closing/locking doors, seamless floors, monolithic ceiling, two doors in series, 50 L/s doorway infiltration, personnel shower (need based on agent) capable of being sealed, and a pass through autoclave. The ABSL3 physical environment shall have controlled access.

In ABSL3 areas all procedures involving the manipulation of infectious materials, agents, and animals must be conducted within a BSC (preferably Class II or Class III), or other physical containment devices. These BSCs are exhausted through HEPA filters in series by separate and independent exhaust systems. PPE, protective lab clothing, gloves and respi-

ratory protection as required by the BMBL and the DOHS shall be worn. In addition, these safety and operational protocols including PPE use is dependant upon the scientific program requirements.

The ABSL3 environment is the secondary containment barrier. An ABSL3 environment shall have a physical separation from the access corridors by way of a vestibule or airlock with self closing doors. Negative airflow into BSL3 laboratories shall be the method for containment of BSL3 agents. The exhaust air shall not be recirculated, and all waste shall be decontaminated.

## C. Space Descriptions

ABSL 3 Animal Housing: The animal housing or caging system chosen is one of the most important elements to consider in the planning process. Animal housing and most procedure space should be carefully designed to facilitate animal wellbeing; meet research requirements; minimize experimental variables; and provide isolation from wide temperature and humidity variations, vibration, and noise sources .The caging system should provide adequate space to permit freedom of movement and normal postural adjustments; a comfortable environment; and an escape proof enclosure that confines animals safely with easy access to food, water, and ventilation. The caging system must also meet the biological needs of animals, e.g., maintenance of body temperature, waste elimination and reproduction.

An autoclave shall be available and convenient to animal rooms where biohazards are contained. The autoclave is used to decontaminate infectious materials and waste before moving it into other areas of the facility.

ABSL3 Procedure Room: An ABSL3 procedure room is essentially a BSL3 laboratory. The design features of an ABSL3 procedure room shall ensure containment of infectious agents used at this biosafety level. The primary containment barrier is the BSC where all procedures are conducted to minimize aerosol exposure to the work environment. The work environment, or containment barrier of the BSL3 laboratory, is the secondary containment barrier. This BSL3 containment barrier consists of the floor, walls and ceiling of the laboratory and shall be constructed to meet the requirements of the “NIH Biosafety Level 3 – Laboratory Certification Requirements”. The primary method of containment within the ABSL3 procedure room environment is directional air flow. The ABSL3 procedure room shall be negative to adjacent spaces of a lesser biosafety level. The concept and criteria for directional air flow and room pressurization gradient is discussed in Chapter 6 HVAC.

Cubical Housing: Cubicles are small rooms or containment compartments within a larger room or suite of rooms. Cubicle housing may be used for isolating animals of different

health statuses, for conducting timed day/night studies, for separation of different species or for specialized barrier areas. Cubicles offer the advantage of isolating a small segment of the animal population and permit housing of multiple species in a single room. Cubicles are particularly useful for quarantine of incoming animals and may preclude the need for a separate quarantine room. Cubicles are also useful in the containment of hazardous substances used in animal studies, provide an added degree of security, and reduce allergens. Cubicle housing areas should be designed to have negative air pressure in relation to adjacent spaces based on intended use of the cubicle. If the cubicles are prefabricated units, they can be readily disassembled to convert the room to other uses. Ideally, cubicles should be designed to accept two single sided rodent racks or one double-sided unit or one NHP racking unit. Although management may decide to utilize static non-ventilated cages within the cubicle, cubicles should be equipped with two exhaust drops to be used if ventilated caging is used in the area. If overhead doors are used on this type of space, consider providing automatic door operators, which have safety devices to prevent operator injury.

ABSL3 Cage Wash: Cages shall be autoclaved or otherwise decontaminated prior to removal from ABSL3 space. The cage wash room houses equipment for cleaning and sanitizing animal cages, trays, lids, and water bottles. In addition, the cage wash area may house bedding disposal and bedding filling equipment and storage for clean bedding. During the planning phase the method and route for feeding, bedding delivery and bedding disposal between the loading dock and the cage wash must be defined. The cage wash should be convenient to animal holding but distant from administration offices and personnel areas. The cage wash facility should be designed and constructed to accommodate high pressure spray systems, humidity, strong chemical disinfectants and very high water temperatures, during the cleaning process.

Anterooms: ABSL3 environments shall have a ventilated anteroom to provide separation from areas with unrestricted traffic flow. This passage shall be arranged with two sets of self-closing doors. The anteroom doors shall be interlocked to prevent simultaneous opening of doors between the outside corridor and containment areas. Interlocks, when present, shall be provided with a manual override for use in case of emergency. Final determination on the design of anterooms for these facilities shall be made in consultation with DOHS personnel.

Showers: Showers shall be designed utilizing a pass through arrangement. Shower-out capability shall be provided in all ABSL3 areas. Design requirements for showers from ABSL3 vivarium are determined based on program need and facility protocols. In addition to the requirements of the BMBL and Chapter 8 Plumbing, the number of showers, arrangements, and sizes shall be based on thru-put analysis of personnel and material flow.

Whole Animal Imaging Equipment Spaces NMRI: Magnetic and RF shielding requirements shall be verified with equipment manufacturer and shielding consultant. All shielding requirements must be coordinated with containment penetrations. Coordination of electrical and plumbing piping shall be performed to minimize the effects of magnetic or RF interference inside the shielded system. The effects of structural components on shielding design (rebar, steel joists, etc.) shall be considered. Proximity of NMRI to adjacent equipment or areas of ferrous activity (loading docks, cart movement, etc.) shall be reviewed for additional shielding and separation requirements. Ceiling heights may be increased due to shielding requirements and may have an impact on overall floor to floor heights. Means and methods for servicing equipment from a non-containment area should be provided if possible.

X-Ray/CT/PET/SPECT: Lead shielding requirements shall be verified with equipment manufacturer and shielding consultant. Lead shielding of penetrations shall be coordinated with containment requirements. Isotope injection and animal recovery areas shall be determined by program. Means and methods for servicing equipment from a non-containment area should be provided if possible.

The design of whole animal imaging systems such as MR, X-Ray, PET, CT and SPECT shall consider serviceability and decontamination from maintenance and biosafety standpoints. Consideration shall be given to whether portions of the equipment shall be located outside of containment for ease of maintenance and serviceability. Should any portion of the equipment be located outside of containment, a containment barrier that integrates the imaging equipment and the animal interface shall be required.

Carcass Disposal: Size, capacity, and method of carcass disposal shall be determined by the animal research facility program. Adjacency to carcass coolers is recommended. New and emerging technologies shall be brought to the attention of the Project Officer for approvals by DEP and DOHS.

## D. Circulation of People, Animals and Materials

Movement of clean and dirty material shall be separated to the greatest extent possible. Movement of animals shall be separated from dirty material to the greatest extent possible. Movement throughout an ABSL3 facility shall be segregated to minimize cross contamination as well as “clean” from “dirty” flows.

All material and animal waste from an ABSL3 facility shall be removed from containment via a pass through autoclave into non-contained space. Materials flowing into the animal space shall pass through an airlock. Each holding room shall have individual protocols. Additional program space along with appropriate protocols may be required for entering/exiting indi-

vidual ABSL3 spaces. Animal areas shall be separated from the procedure area by a visual and acoustic barrier as required by AAALAC.

## D.1 Dual Corridor System:

Contamination control is the primary rational for choosing a dual corridor system. The dual corridor system has animal holding rooms leading to two separate corridors that are dedicated clean and dirty corridors for the movement of cages. The flow of cages is unidirectional and may involve two single loaded corridors in a small facility, one double loaded and two single loaded corridors in a larger facility. Dual corridors are not an efficient use of space and will increase the gross to net ratio.

## E. Mechanical, Plumbing and Electrical Services

Separate and independent supply and exhaust systems are provided. Exhaust air is HEPA filtered. The amount of contaminated ductwork should be minimized.

Ventilation: Ventilation to the vivarium should be provided in accordance with the *Guide for Care and Use of Laboratory Animals*. The direction of airflow into the animal facility is inward; animal rooms must maintain inward directional (negative) airflow compared to adjoining hallways. A ducted exhaust air ventilation system shall be provided. Exhaust air is discharge to the outside without being recirculated to other rooms. This system creates directional airflow which draws air into the animal room from less contaminated areas and toward more contaminated areas.

Ventilation system design should consider the heat and high humidity load produced during the cleaning of animal rooms and the cage wash process. The exhaust must be dispersed away from occupied areas and intakes and is single HEPA filtered. Provide visual monitoring devices that indicate and confirm that directional inward airflow is provided at the animal room entry. Provide an HVAC control system to prevent positive pressurization to animal spaces. Audible alarms shall be provided to notify personnel of ventilation and HVAC system failure.

Utilities: Vivarium services, including hot and cold water, $CO_2$ gas, and liquid nitrogen are surface mounted. Spare capacity is recommended. ABSL3 utilities shall be sealed to the ABSL3 containment barrier and shall be constructed to meet NIH Biosafety Level 3 – Laboratory Certification Requirements.

- Service penetrations shall have backflow prevention.
- The HVAC exhaust shall have single HEPA filtration as discussed in Chapter 6 HVAC.
- Specific laboratory gases vary in each case and are dependant upon scientific program.

- Central vacuum is typically not recommended.
- Exposed conduit, piping or pathways are to be resistant to decontamination chemicals.
- Internal facility appurtenances, such as light fixtures, air ducts, and utility pipes, shall be arrange to minimize horizontal surface areas, to facilitate cleaning and minimize the accumulation of debris or fomites.
- Emergency eyewash is readily available.
- All animal rooms must contain a hand wash sink near the door.

Electrical service to the area is from a redundant electrical system backed by standby generators. Electrical and data outlets are integral to the containment barrier. Conductors for power data or any other system are sealed so that the penetration meets the criteria of the room-tightness integrity testing.

ABSL3 Lighting: Lighting shall be surface mounted with a single penetration for each fixture. Light fixture housing shall be of a material or finish that resists the corrosiveness of decontamination chemicals; shall be smooth for wipe down and to prevent the snagging or tearing of protective gloves. Fixtures shall be sealed to the ceiling or wall to prevent harborage of pests or vermin. Illumination shall be adequate for all activities, avoiding reflections and glare that could impede vision.

Inward Airflow: Biocontainment laboratories will be divided into zones that demark the level of containment required. The deepest negative pressure would be maintained in the zone that is considered the highest level of biosafety and/or biosecurity risk. The mechanical and control section will discuss the pressure differentials required for each zone, and the methods for monitoring and maintaining pressures within each zone.

Outside Air Infiltration Control: Air infiltration from the exterior wall can have an effect on the air balance of the interior rooms in a facility. For that purpose, it is recommended that the exterior wall be designed to minimize the amount of air leakage into a zone containing ABSL3 animal facilities. Consider the need for a buffer zone between the containment facility and the outside wall is recommended.

## E.2 Decontamination

A method of decontamination of all infectious material must be available within the facility, preferably within the areas where infectious materials and animals are housed and manipulated (e.g. autoclave, chemical disinfection, or other approved decontamination methods). Consideration should be given to means for decontaminating routine animal husbandry equipment, sensitive electronic and medical equipment. DOHS shall be consulted to determine appropriate use of decontamination chemicals and the protocols that govern decon-

tamination methods. Rooms shall be capable of being sealed for protocols that require gaseous decontamination in accordance with NIH Biosafety Level 3 – Laboratory Certification Requirements.

Equipment must be decontaminated before repair, maintenance, or removal from the areas where infectious material and/or animals are housed or manipulated.

The scientific program along with the review of the by DOHS shall be required to verify the decontamination methods and types of chemicals used in the facility. The A/E shall evaluate the building systems for compatibility.

Decontamination systems are discussed elsewhere in the DRM and include items such as pass through devices, decontamination equipment, carcass disposal, liquid decontamination and other methodologies used in the containment environment. See Section 1-9 Environmental Management/Radiation Safety."

## 2-6-30 Design Document Requirements

### A. Program of Requirements

Project Officers are encouraged to use the information in this section to prepare PORs for NIH ABSL3 animal research facilities. A POR for the specific project shall be developed in accordance with Volume I Section 2-5 of the HHS Facilities Program Manual. In addition the programming process shall address user needs, population density, building circulation, mechanical, electrical, and plumbing systems, and all aspects of safety.

### B. NIH Facility Budget Estimates

NIH Planners and Project Officers are encouraged to use the information in this section to prepare budget estimates for NIH animal research facility.

### C. HHS Facility Project Approval Agreements

Project Officers are encouraged to use the information in this section to prepare FPAAs for NIH ABSL3 animal research facility facilities.

### D. Project Definition Rating Index

Project Officers are encouraged to use the information in this section to enhance their PDRI scores.

## E. Laboratory Concept Design

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this section as a reference in developing their conceptual design for their NIH ABSL3 animal research facility project.

### E.1 Outline Specifications

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this section as a reference in developing their outline specifications for their NIH ABSL3 animal research facility project.

### E.2 Square Foot or Broad Order of Magnitude Cost Estimate

Architects and Engineers under contract to the National Institutes of Health are encouraged to use the information in this section as a reference in developing their broad order of magnitude cost estimate for their NIH animal research facility project.

## F. Special Requirements:

### F.1 Risk Assessment:

A risk assessment shall be performed to determine the level of threat to the local environment, as directed by DPSM.

### F.2 Protocol Development:

Building operations and maintenance protocols shall be developed in conjunction with the design and engineering of the facility. Scheduled maintenance of the building containment components and systems shall be developed. The following shall be considered:

- Duration of the scientific program.
- Standard protocols for maintaining the lab during shut down periods.
- Location of equipment inside and outside of containment.
- In situ decontamination of lab components (i.e., HEPA filters)
- Monitoring of all life safety systems.

### F.3 ABSL3 Pre-Testing, Commissioning and Certification:

The A/E shall reference the most current versions of the following documents listed as NIH acceptance criteria for pre-testing, commissioning and certifications. Testing criteria for a ABSL3 is as follows:

- BSC Certification – NSF Standard 49.
- All HEPA filters shall be tested using IEST-RP-CC001.3 or an APPROVED equivalent test procedure. Poly-Alpha Olefin (PAO) shall be used in lieu of Di-Octyl Phthalate (DOP) as a traces gas.
- Liquid decontamination system (if installed) Biological Challenge Test Requirements.

- NIH Biosafety Level 3 – Laboratory Certification Requirements..
- Autoclave Testing and Biological Challenge Test Criteria.
- Chemical resistance criteria of materials.
- Certification of local exhaust devices, e.g., downdraft and necropsy tables.

## F.4 Containment Barrier Validation:

To receive commissioning approval, surfaces shall meet the following criteria:

- Uniformity of texture.
- Smooth surface finish.
- Acceptable hardness.
- A minimum number of symmetrically spaced form seams.
- All pit and pinholes larger than 5 mil are to be filled.
- All projections shall be removed to a level flush with the surface.
- Corners and surfaces shall be plumb and square.
- Porous or defective substrates shall be repaired.
- Patching shall be done using only a manufacturer's approved high performance coating bonding agent and crack filler.

# Civil Engineering & Site Development

3



# Section 3-1: Site Development



## 3-1-00 Design Requirements

NIH campuses are developed to provide pleasant environments for the enhancement of the research. An important part of this environment is the campus-type setting with attractive landscaping and a minimum of paving. The important research conducted at NIH requires the support facilities to be constructed to the highest standards available in the industry to minimize disruption caused by repair and reconstruction. The Office of Research Facilities has prepared campus Master Plans for buildings as well as underground utility services. These plans shall be followed.

New buildings or additions shall be coordinated with the OFP and located in conformance with the NIH Campus Master Plans.

- Preserving existing natural features such as trees, slopes, and drainage characteristics, whenever possible.
- Providing vehicular/pedestrian access that blends with the existing traffic pattern.
- Providing access for emergency vehicles, including fire and police.
- Phasing construction projects that impact day-to-day NIH activities to minimize disruption to the campus.
- Identifying contractor staging areas and reasonable space provided for contractor parking, various trailer types (including storage, materials and office), dumpsters, cranes, delivery vehicles, maneuvering, and other site-specific factors.

### A. Reference Codes and Standards

The A/E shall use and comply with the design and safety guidelines, and references listed in Appendix A, and other safety guidelines received from the NIH Project Officer or as required by the program. The A/E shall utilize the latest editions of reference design and safety guidelines available at the time of the design contract award.

The following standards shall be followed when constructing new structures on NIH campuses.

- NIH Campus Master Plans in locating new campus facilities
- NIH Master Utility Plans in locating existing campus utilities
- NIH Tree Inventory

## 3-1-10 Design Guidance

### A. Grading:

Proposed grading plans shall be coordinated with ORF. Maximum slopes on lawn areas shall be 3:1. A retaining wall with a safety railing shall be provided for any slope greater than the maximum defined slopes for lawns. Minimum slopes on lawn areas shall be 2% positive slope away from buildings. Maximum slopes of sidewalks shall not exceed 8% unless approved by the ORF. Standard 50mm pipe railing, with an intermediate horizontal stile, painted black, shall be installed when the slope exceeds 5 percent. Slope limitations and rest points shall comply with ABA.

### A.1 Stockpiling:

Stockpiling is strongly discouraged, however may occur on a project-by-project basis, if in compliance with all of the following conditions:

- Prior approval from DEP
- Excavated material quantities less than 76CM
- Excavated material stored within the limits of disturbance (LOD)

### B. Sediment and Erosion Control:

Sediment and erosion control (SEC) drawings shall be prepared for construction that results in ground disturbance in states or local jurisdictions, where required. NIH policy regulates on-campus SEC to the maximum practicable extent. Any construction that results in ground disturbance shall be subject to the NIH SEC protection policy, on a project specific basis. The Project Officer shall contact the DEP for specific guidance. The A/E shall prepare SEC permit drawings and submit to DEP through the Project Officer for review.

### C. Storm Water Management

To ensure proper water quality, all drainage systems that collect runoff from parking areas shall be provided with appropriate exterior-type oil, sand, and grease interceptors to serve segregated waste streams for specific functions as necessary to ensure compliance with EPA discharge regulations, and minimize potential maintenance issues for NIH campus infrastructure. Drainage from intermediate parking garage levels shall discharge to sanitary through an appropriate oil/sand interceptor. Only the top deck, exposed to rainfall, may discharge to the storm water system.

# 3-1-20 Design Information & (Local Requirements)

## A. Reference Codes and Standards

The following standards should be followed when constructing new structures on NIH campuses located in Montgomery County, Maryland:

- Maryland Department of Transportation State Highway Administration Standard Details for installation of storm drains
- Washington Suburban Sanitary Commission for installation of domestic water and sanitary sewer
- Montgomery County Department of Transportation, Standard Details for Road-ways, for installation of roadways, parking, and miscellaneous appurtenances
- Maryland Department of Environment (MDE), Standard Details for Sediment Control and Storm Water Management

## B. Sediment and Erosion Control:

For NIH projects located in Maryland, when a project nears or exceeds the Maryland Department of the Environment (MDE) threshold defined as a disturbance of 465 m2 of existing ground or the movement of 76 m3 of soil, an MDE permit for SEC is required. SEC projects with greater than 4,000 m2 of disturbance shall comply with MDE General Permit Number 97-GP-0004, which requires additional inspections. Additional fees, record-keeping, and other requirements may also apply.

The A/E shall make a submission to the MDE (or state where required) when it has been deter-mined by DEP that the documents meet state requirements. It is highly recommended that an MDE review be made through an MDE-approved “expedited” reviewer. No site work shall commence prior to holding a SEC preconstruction meeting with the MDE inspector when a permit is required. When a permit is not required, the installation of SEC required by DEP shall be in place before site work begins

## C. Storm Water Management:

All construction shall meet the requirements of the MDE and the NIH Master Plan for storm water management.

# 3-1-30 Design Document Requirements

## A. Site Development Plan

Plans profiles, details based on existing topography reference to project benchmarks, metes and bounds surveys and storm water calculations showing but not necessarily limited to: location of building(s), roads, service areas, major site features, easements and other legal constraints, set backs etc.

## B. Sediment Control Plan:

Plans and details showing erosion control measures.

## C. Outline Specifications

Outline specifications shall be developed at the design development stage

## D. Detail Performance Specifications

Detail performance specifications shall be developed at the contract document stage.

## E. Systems Cost Estimates

Systems cost estimates shall be developed at design development stage.

## F. Quantity Takeoff Estimates

Quantity takeoff estimates shall be developed at the contract document stage.

# Section 3-2: Site Utilities



## 3-2-00 Design Requirements

Existing utilities shall be located by referencing the NIH Master Utility Plan. The DPM maintains the master plan for underground utility services for reference during the preparation of site design. Preliminary site work considerations shall include:

- Retaining the services from a qualified geotechnical engineer licensed to practice in the state where work occurs (See Section 5-1-00-E"Geotechnical Report").
- Verifying locations of existing utilities with frequent test pits using vacuum dig techniques to avoid disruption to the campus.
- Testing all existing underground steam and condensate piping to be disturbed for asbestos-contaminated insulation.

### A. Field Confirmation:

All branch utility connection points shall be field verified and validated during the project design phase by the A/E of Record.

### B. Profiles:

Underground utilities design shall include profiles for all main lines and major laterals. Electrical duct bank profiles shall slope away from buildings to the first manhole. Cover shall be a minimum of 762 mm and sufficient to keep the utility line below the local frost line.

### C. Manholes:

Manholes shall be provided at all changes in direction on utility lines 200 mm and larger for storm and sanitary sewers, and at all points of connection. NIH numbers shall be brazed on manhole covers.

### D. Cathodic Protection and Corrosive Soils:

Designs shall include requirements for testing of soil for stray currents and/or corrosive soils, and cathodic protection of underground metallic piping.

# 3-2-10 Design Guidance

## A. Site Utilities:

Utility branch design for new facilities or renovations to existing facilities shall include complete utility service branch supply/return systems including underground tunnels, vaults, trenches, duct banks or routes through existing structures. The new branch designs shall be inclusive and extend from the new facility mechanical rooms to the existing supply source and include all required inline, monitoring and control devices. No structure may be constructed above underground utilities. Utility systems shall be relocated to areas that provide clear access for maintenance when required by the structural design.

## B. Utility Connections:

All planned connections to the central utility systems and revisions to the NIH piping or electrical distribution networks shall be reviewed and approved by the Utility Operations Branch (UOB) for compliance to NIH requirements in accordance with the NIH QSM. The applicable systems include all utility distribution systems, return systems for steam/condensate, electrical, IT/LAN, chilled water supply/return, compressed air, potable water, natural gas, storm and sanitary sewer. This also encompasses campus utility distribution lines (not building service connections) that traverse basements, crawl spaces, mechanical or electric rooms, under foundations, over structures, and interstitial space.

# 3-2-20 Design Information & (Local Requirements)

## A. Utility Service:

The table below provides an abbreviated summary of approved materials. Refer to the HVAC section of the DRM for detailed criteria for materials, applications, and joints which is to be utilized as a supplement to the table below

| Utility | Minimum Size | Material |
|---|---|---|
| Storm Drain | 300 mm | RCP or Ductile Iron |
| Sanitary Sewer | 150 mm | PVC SDR 35, SDR 26,or Schedule 40, or Epoxy line ductile iron. Select as required for application and loading |
| Domestic Water | 150 mm | Cement Lined Ductile Iron |
| Chilled Water | >= 150 mm | Steel Extra Heavy Seamless, weld joint |
| Chilled Water | < 150 mm | Steel Schedule 40 Seamless weld |

| Utility | Minimum Size | Material |
|---|---|---|
| Steam | >= 150 mm | Steel Extra Heavy Seamless, weld joint |
| Steam | < 150 mm | Steel Schedule 40, weld joint |
| Condensate | < 150 mm | Stainless Steel Schedule 40, weld joint |
| High Pressure Drip | N/A | Stainless Steel Schedule 40, weld joint |
| Natural Gas | N/A | Polyethylene fusion joint |
| Compressed Air | > 100 mm | Steel Schedule 40 welded and cleaned and dried of contaminates, grease, oil, and particulates, or ASTM B819 Type K copper, cleaned and capped for oxygen service standards, clean brazed. |
| Compressed Air | <= 100 mm | ASTM B819 Type K copper, cleaned brazed |

## A.1 Required Computer Modeling

The NIH has developed extensive computer modeling for existing utilities. Expansion of these utilities requires the use of the following programs for analysis:

| Storm Drain | EDS Storm Drain |
|---|---|
| Sanitary Sewer | EDS Sewer |
| Domestic Water | KY Pipe |
| Chilled Water | KY Pipe |
| Steam | Steamnet |
| Other | No Standard |

## B. Washington Suburban Sanitary Commission (WSSC) Compliance:

The design and installation for utility piping systems located on the NIH campus including: domestic water supply, sanitary and storm sewer, shall comply with all the WSSC requirements, general conditions and standard specifications, and shall be identified clearly in applicable design drawings and specifications. Maximum long term deflection in gravity sewer lines shall not exceed 5%. Initial deflection shall be calculated and vertical ring deflection shall be measured in each plastic pipe section not soon than 30 days after final trench backfill to grade. Proper alignment, slope, throust restraint, and backfill criteria shall be rigdidly specified and monitored.

### C. Washington Gas Compliance:

Utility piping systems located on the NIH campus for natural gas service shall comply with all requirements of Washington Gas.

## 3-2-30 Design Document Requirements

### A. Site Utility Plans

Plans, profiles, details, schedules, etc based on existing topography reference to project benchmarks and utility surveys showing but not necessarily limited to: location of all utilities above and below ground, manholes with invert elevations, building(s), roads, service areas, major site features, easements and other legal constraints, set backs, etc.

### B. Storm Water Plans

Plans, profiles, sections, details, schedules etc. based on existing topography reference to project benchmarks showing but limited to storm water improvements such as swales, ditches, culverts, storm drains, storm water inlets etc.

### C. Outline Specifications

Outline specifications shall be developed at the design development stage

### D. Detail Performance Specifications

Detail performance specifications shall be developed at the contract document stage.

### E. Systems Cost Estimates

Systems cost estimates shall be developed at design development stage.

### F. Quantity Takeoff Estimates

Quantity takeoff estimates shall be developed at the contract document stage.

# Section 3-3: Site Improvements



## 3-3-00 Design Requirements

### A. Preliminary Planning Criteria

New buildings or additions should be coordinated with the Office of Facilities Planning and located in conformance with the NIH Campus Master Plan to minimize disruption to existing campus operations including utilities, traffic, parking, pedestrian access, and mature trees. Vehicular and pedestrian access should blend with existing traffic patterns. Access for emergency vehicles, including fire and police, must be provided.

Borings and geotechnical reports should be obtained from a qualified geotechnical consultant licensed to practice in the state where the work is to be implemented and the report should include a preliminary recommendation for sheeting and shoring. All existing underground steam and condensate piping to be disturbed should be tested for asbestos-contaminated insulation. Existing natural features such as trees, slopes, and drainage characteristics should be preserved whenever possible. The construction of large and significant projects that impact day-to-day NIH activities should be phased to minimize disruption to the campus.

Contractor staging areas should be identified as early in the project as possible and reasonable space provided for contractor parking, trailers, cranes, delivery vehicles, maneuvering, and other site-specific factors. The staging areas should be surrounded with a temporary 1 800-mm chain link fence with brown plastic screening material.

# 3-3-10 Design Guidance

## A. Parking and Paving

Roadway and parking lot paving sections shall conform to the following: The size and types of parking spaces should be in conformance with local zoning regulations. Handicapped spaces should be adjacent to buildings whenever possible.

| Area | Item | Paving Section |
|---|---|---|
| Parking Lot | Sub-base | Compacted soil base |
| | Base | 100 mm base course bituminous concrete (BI)-one lift |
| | Surface | 50 mm surface course bituminous concrete (ST)-one lift |
| Roadways | Sub-base | Compacted soil base |
| | Base | Two;100 mm lifts of base course bituminous concrete (BI) |
| | Surface | 50 mm surface course bituminous concrete (ST)-one lift |

### A.1 Traffic Line Striping for Roads and Parking Lots:

Paint shall be approved lead free, VOC compliant, fast drying, and 100% acrylic waterborne traffic paint. An MSDS shall be submitted for each product. White traffic paint shall be a premium grade with 78% total solids by weight and containing additional resin and titanium dioxide. Painting shall only be allowed when pavement surfaces are dry and clean. Pavement surface temperatures shall be at or above 5°C and rising. A wet film thickness of 12-15 mils shall be required. New striping shall match existing line widths with no line being less than 100mm width.

Strong Yellow Green crosswalk tape shall be thermoplastic marking tape. Where required, this heat applied product shall be applied strictly following manufacturer's recommendations. Tape shall be alternating 200mm minimum lengths of 200mm wide Strong Yellow Green and 300mm wide White. There shall be a 150mm gap between tape strips. Other crosswalks shall be painted white.

## B. Sidewalks, Curbs and Gutters:

Sidewalks, Curbs, and Curbs/Gutters: Optimum sidewalk width is 1 830 mm, with 1 525 mm as the minimum. The sidewalk concrete design mix shall be a minimum of 90 mm, 25 MPa, 6% to 8% air entrainment, 1 kg of powdered carbon black per 1.3 m3 (or at the rate of 19 L of liquid carbon black per 12 m3) of concrete and sealed with clear curing compound.

## B.1 Sidewalks to Major Building Entrances and Major Building Feature Areas:

Durable, air-entrained, colored (other than carbon black), stamped concrete may be used for these areas.

## B.2 Material Exclusions for Curbs and Curb Gutters:

Granite curbs are not permitted on any NIH projects.

## B.3 Material Exclusions for Common Pedestrian Sidewalk Areas Subject to Use by Snow Removal Equipment:

The following materials are not permitted on any NIH projects because of maintenance requirements or safety concerns:

- Cobblestones.
- Asphalt hex pavers on asphalt base.
- Exposed aggregate concrete.
- Any type of paver material on gravel/sand base course.
- Pavers on plastic blocks.
- Pre-cast concrete interlocking pavers on sand base.
- Granite, brick, or slate on concrete base.

## C. Loading Docks, Delivery and Service Areas:

All new campus buildings and buildings subject to major retrofitting require the installation of loading docks. The primary purpose of the loading dock is to facilitate movement of materials into and out of buildings. Loading docks should be located in areas of the building that are separated from normal daily pedestrian and vehicular traffic, and should be sized for safe maneuvering as well as for loading and unloading equipment such as pallet trucks.

Loading docks should be sited to prevent the entry of pests and designed to create an effective barrier between the outside of the facility and the interior. Loading docks are a functional extension of the facility, and should be designed and managed to facilitate proper and efficient movement of materials into and out of the facility along with a dockyard that is easily cleaned and maintained. Current and future facility needs should be taken into consideration when planning and designing allocated space for loading docks. Facilities expand, needs change, and docks should be conceived with long-term viability in mind.

For additional information, see General Design Guidelines, Section - Architecture and Section - Structural. For additional loading dock requirements specific to Animal Facilities, see Section 2-4 Animal Research Facilities – Programmatic Goals and Objectives.

## C.1 Access and Truck Size:

Access to loading docks will be directly from NIH campus roads. No access through parking lots will be permitted. Roadways leading to loading docks and adjacent tarmacs should be of sufficient size and configuration to accommodate various sized vehicles up to and including tractor-trailer class.

## C.2 Drainage and Grading:

Adequate drainage should be provided by use of trench drains or positive drainage away from the dock, with a minimum gradient of one (1.0) percent.

## C.3 Lighting:

Exterior building lighting in the loading dock area should be indirect to the loading dock to reduce the attraction of flying insects. Do not use wall-mounted lighting and do not install lights directly above receiving or personnel doors.

## D. Parking and Wheel Chocks:

Tarmacs on-grade must have wheel chocks available that meet OSHA requirements. Adequate short-term parking should be available for courier service vehicles.

## E. Snow Removal Areas:

Areas for piling snow from snow removal operations are desirable and should not block the dumpster or the loading dock. Heated pavement is not permitted for snow removal due to maintenance and energy concerns.

## F. Screening:

Visual screening of all loading areas is desirable to minimize audible and visual disruption to the NIH campuses and surrounding communities. Screening can consist of fences, walls, landscaping, etc. Landscaping in the area of loading docks should minimize cover and harborage for birds and rodents. Ivy and other low-growing, dense ground cover in the vicinity of loading docks is not recommended. Screening should be carefully coordinated with security and closed circuit television requirements.

## H. Fences:

Staging areas shall be surrounded by a temporary 1 800 mm chain-link fence with brown plastic screening material. Where possible pedestrian hazard occurs, solid wood fencing shall be provided. Decorative fencing shall be located and designed in accordance with the NIH Campus Master Plans, and under the review and approval of the NIH ADRB. All critical exterior utility equipment, including but not limited to generators, transformers, AHU's, etc.,

require permanent security fencing. Security fencing shall meet the requirements set forth by DPSM.

## 3-3-20 Design Information

### A. Parking at the Bethesda Campus in Montgomery County, MD:

Parking for vehicles shall be coordinated through the ORF and provided in conformance with the NIH Memorandum of Understanding (MOU) with Montgomery County.

## 3-3-30 Design Document Requirements

### A. Plans

Plans and details showing but not necessarily limited to: location of building(s), roads, and service areas

### B. Outline Specifications

Outline specifications shall be developed at the design development stage

### C. Detail Performance Specifications

Detail performance specifications shall be developed at the contract document stage.

### D. Systems Cost Estimates

Systems cost estimates shall be developed at design development stage.

### E. Quantity Takeoff Estimates

Quantity takeoff estimates shall be developed at the contract document stage.

# Section 3-4: Landscaping



## 3-4-00 Design Requirements

The selection of plant materials shall be coordinated with ORF during early design stages. Select plant material native to the region. Avoid invasive exotic material. All disturbed areas not paved or landscaped shall be restored with state or local jurisdiction-approved certified sod on a minimum of 75 mm of topsoil.

## 3-4-10 Design Guidance

### A. Landscape Lighting Design Considerations:

### A.1 Safety and Security:

Exterior campus lighting is critical to safety and security. Lighting shall minimize dark areas suitable for hiding. Landscaping shall not interfere with camera surveillance views. For specific requirements, see Electrical Section 10-5-10-C “Exterior Lighting,” and coordinate security lighting and camera surveillance with DPSM.

### A.2 Pest Management:

Lights are attractive to insects and to some vertebrates. The type and placement of lights around and in a facility can impact the occurrences of pests and nuisance incidental invaders indoors. Wherever possible, locate lights away from the building, thereby attracting pests away from the building. Lights shall not be placed directly over loading dock doors or personnel doors. Lights that are less attractive to insects, such as sodium vapor types or any other non-bright white light are recommended where fixtures are mounted within 1 000 mm of door. Avoid light fixture design and installation that provide pest harborage outside a building, such as overhead lights with a flat upper surface which serve as nesting or roosting sites. The power conduit for the lights shall be designed so there is no provision for roosting or nesting sites for nuisance birds.

## B. Other Landscape/Pest Management Considerations:

An open perimeter boundary around the entire facility is required. A 610 mm-wide by 100 mm-deep egg-sized washed river stone with a physical weed geotextile shall be provided around all new or newly landscaped buildings for pest management. Aluminum or steel edging shall be used around the barrier. This barrier shall be wide enough to facilitate inspections around the building, shall be constructed from durable materials; shall not obstruct grass-cutting or maintenance activities; and shall prevent encroachment of grasses or weeds around the exterior of the building.

All planting beds shall begin outside the gravel strip. Mulches shall be bulk bagged or double shredded hardwood, cypress mulch, or pine bark fines. Mulch shall be applied to a compacted depth of 75 mm.

Landscape planting impacts the number and types of pests found around the exterior of the building, as well as within the building envelope. The following shall NOT be used in NIH projects:

- Dense ground covers such as ivy, providing harborage for rodents.
- Ornamental plants such as spirea, attracting certain beetle species that can become indoor pests.
- Raised planters or garden beds, which can be nesting sites for rodents.
- Dense foundation plantings, reducing air circulation around buildings, harboring pests such as wasps, and obstructing pest management survey and control activities.

## C. USDA Plant Hardness Zones

The NIH has several campuses throughout the United States and it is recommended that NIH facilities program used the USDA's Plant Hardness Maps to determine which plant are suitable for their campuses. (See Exhibit X3-4-A: USDA Plant Hardness Maps.)

NIH campuses located in Maryland are located in Zones 6 and 7. The following are representative plants in Zones 6 and 7 in which they normally succeed:

Zone 6
-10 to 0 F
-23.3 to -17.8 C

Acer palmatum (Japanese maple)
Buxus sempervirens (Common boxwood)

Euonymus follunei (Winter creeper)
Hedera helix (English ivy)
Ilex opaca (American holly)
Ligustrum ovalifolium (California privet)

Zone 7
0 to 10 F
-17.8 to -12.3 C

Acer macrophylium (Bigleaf maple)
Rhododendron Kurume hybrids (Kurume azalea)
Cedrus atlantica (Atlas cedar)
Cotoneaster microphylla (Small-leaf cotoneaster)
Ilex aquifolium (English holly)
Taxus baccata (English yew)

NIH campuses located in North Carolina are located in Zone 7. The following are representative plants in Zone 7 in which they normally succeed:

Zone 7
0 to 10 F
-17.8 to -12.3 C

Acer macrophylium (Bigleaf maple)
Rhododendron Kurume hybrids (Kurume azalea)
Cedrus atlantica (Atlas cedar)
Cotoneaster microphylla (Small-leaf cotoneaster)
Ilex aquifolium (English holly)
Taxus baccata (English yew)

NIH campuses located in Montana are located in Zone 5. The following are representative plants in Zones 5 in which they normally succeed:

Zone 5
-20 to -10 F
-28.9 to -23.3 C

Cornus florida (Flowering dogwood)
Deutzia gracilis (Slender deutzia)
Ligustrum vulgare (Common privet)

Paithenocissus tricuspidata (Boston ivy)
Rosa multiflora (Japanese rose)
Taxus cuspidata (Japanese yew)

## 3-4-20 Design Information

### A. Trees:

When any trees exist within the LOD of a project, NIH shall conform to the MDE Forest Conservation Plan (FCP). NIH Tree Replacement Policy requires one-to-one replacement. Replacement deciduous trees shall be a minimum of 38mm caliper; evergreens shall be a minimum of 1 220 mm in height; and major shrubs shall range between 460 mm and 610 mm in crown width. Plants shall be specified to be nursery grown and delivered in containers or balled burlap.

Any project involving exterior work shall identify and make note of any trees within the LOD and re-place regardless or reason for tree elimination, including removal to accommodate the project or tree sickness. This policy applies specifically to the NIH Bethesda and Poolesville campuses.

Currently, the NIH Urban Forest Conservation Plan (NIH UFCO, FCP#C06-04) does not reside in an electronic “linkable” format. The NIH UFCP incorporates the required elements of the Maryland Forest Conservation Act (MFCA), includes the 1:1 tree replacement policy and standard tree protection measures, and has been prepared to comply with the MFCA in support of the NIH Master Plan.

Any project that requires an SEC permit from MDE shall submit a project specific FCP in order to maintain the NIH UFCP. Subsequent construction projects are updates to the NIH UFCP but do not need to go through extensive Maryland Department of Natural Resources (DNR) review. A project specific FCP shall be prepared by a Maryland licensed forester, licensed landscape architect, or other qualified professional. Any work performed on trees, including limb and root pruning or cutting, shall be performed by a Maryland licensed tree expert. Upon completion of the project, the plans shall be properly certified by a qualified professional. All documentation for a project specific FCP shall be submitted to the Environmental Compliance Branch (ECB) and contain the following:

- Project Name and Project Officer Identification.
- Name of Maryland qualified professional who prepared the plan and shall CERTIFY upon completion of the project that the plan has been completed in accordance with the plan.

- Area of permanent additional soil disturbance.
- Number of trees to be removed.
- Number of trees to be relocated.
- Number of trees to be planted.
- A copy of one of the following project plans:
  - SEC plan,
  - Landscape plan, or
  - Simplified FCP application.

The A/E shall consult with the ECB and DEP for additional guidance/updates and for final review and regulatory follow up. The NIH landscape architect (grounds maintenance unit) handles the technical review in regards to planting plans, tree relocation and selection of species etc., while the environmental compliance staff handles the technical regulatory review. Both units work together and maintain and update the NIH UFCP.

See http://www.dnr.state.md.us/forests/programapps/tel.html for information on licensed tree experts. Additional guidance can be obtained from the DNR. Tree protection regulations and qualified professionals listing can be found at http://www.dnr.state.md.us/forests/programs/urban/explained.html and http://www.cbf.org/citizenguides/final_forest_conserv_site/1fc_tableofcontents.htm.

The following table includes trees, shrubs, grasses and flowers compatible with existing NIH plantings and standard practices:

| Deciduous Trees | | | |
|---|---|---|---|
| I. | Oak: Willow, Pin, Scarlet, Red, and White | VIII. | Maple: Red (Red Sunset), Sugar (Green Mountain) |
| II. | Honeylocust | IX. | Sophora Japonica |
| III. | Little Leaf Linden | X. | Amelanchier |
| IV. | Dogwood: Florida/Kousa/Mas | XI. | American Hornbeam |
| V. | Cherry Varieties | XII. | Hawthorn |
| VI. | Redbud | XIII. | Crepe Myrtle |
| VII. | Crab Apple | | |

| Evergreen Trees | | | |
|---|---|---|---|
| I. | Pine: Black, White, Austrian | IV. | Chinese Holly |
| II. | Canadian Hemlock | V. | Norway Spruce |

| Evergreen Trees | | | |
|---|---|---|---|
| III. | American Holly | VI. | Cedar |

| Major Shrubs | | | |
|---|---|---|---|
| I. | Azalea Varieties | VII. | Japanese Holly |
| II. | Rhododendron | VIII. | Juniper |
| III. | Forsythia | IX. | Boxwood |
| IV. | Euonymus Fortunei | X. | Abelia |
| V. | Viburnum | XI. | Taxus |
| VI. | Cotoneaster | XII. | Weigela |

| Grasses and Flowers | | | |
|---|---|---|---|
| I. | Maryland certified improved tall fescue (grass) | III. | Temporary Erosion Seeding (grass) |
| II. | Permanent Seeding - Any 3 varieties. NO Kentucky 31 | IV. | King Alfred Daffodils (Spring bulbs) |

## 3-4-30 Design Document Requirements

### A. Landscape Plans

Plans, Schedules and details showing but not necessarily limited to: location of building(s), roads, service areas, walks, plazas etc.

### B. Outline Specifications

Outline specifications shall be developed at the design development stage

### C. Detail Performance Specifications

Detail performance specifications shall be developed at the contract document stage.

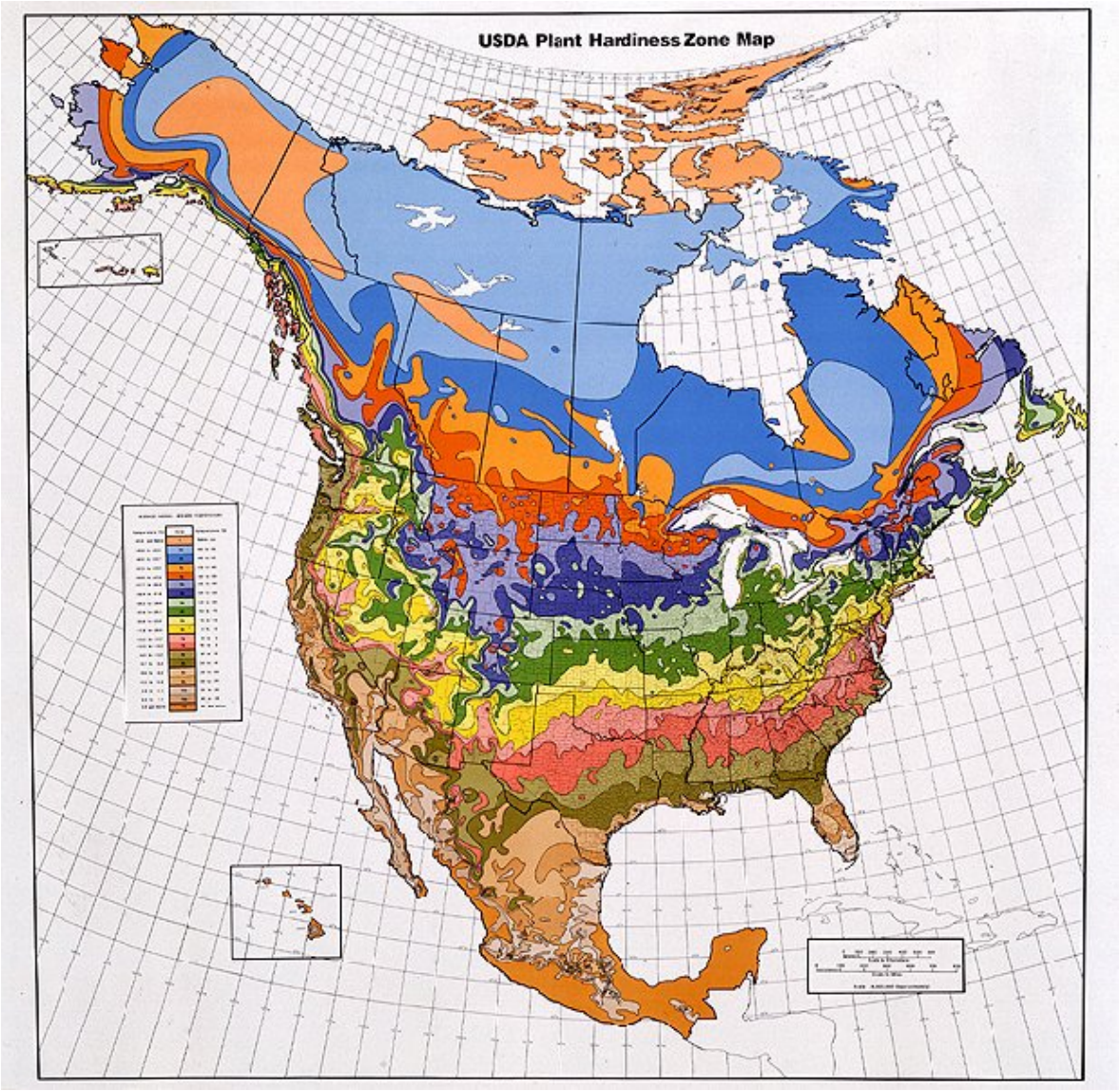
### D. Systems Cost Estimates

Systems cost estimates shall be developed at design development stage.

### E. Quantity Takeoff Estimates

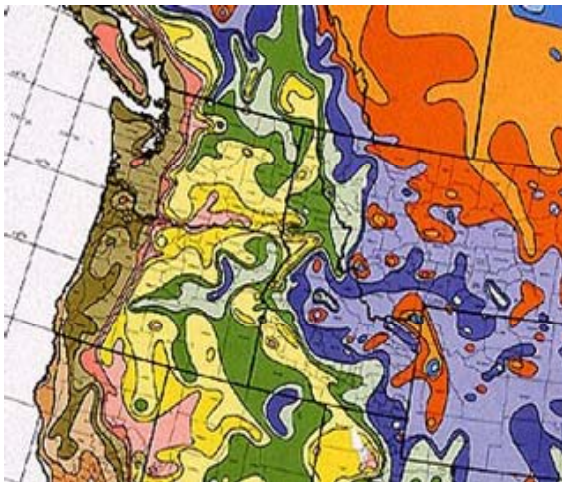
Quantity takeoff estimates shall be developed at the contract document stage.

# USDA Plant Hardiness Maps



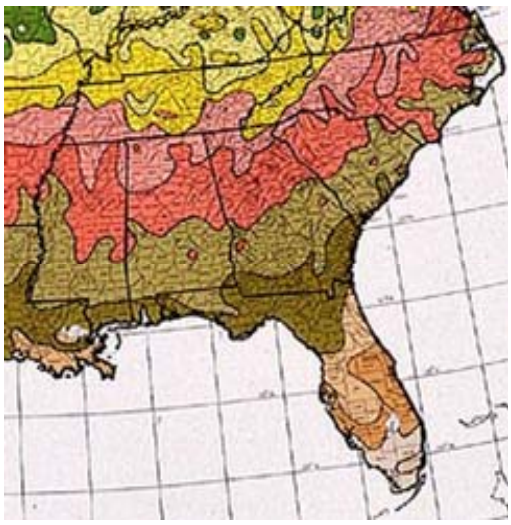
## USDA Hardiness Zones and Average Annual Minimum Temperature Range

| Zone | Fahrenheit | Celsius | Example Cities |
|---|---|---|---|
| 1 | Below -50 F | Below -45.6 C | Fairbanks, Alaska; Resolute, Northwest Territories (Canada) |
| 2a | -50 to -45 F | -42.8 to -45.5 C | Prudhoe Bay, Alaska; Flin Flon, Manitoba (Canada) |
| 2b | -45 to -40 F | -40.0 to -42.7 C | Unalakleet, Alaska; Pinecreek, Minnesota |
| 3a | -40 to -35 F | -37.3 to -39.9 C | International Falls, Minnesota; St. Michael, Alaska |
| 3b | -35 to -30 F | -34.5 to -37.2 C | Tomahawk, Wisconsin; Sidney, Montana |
| 4a | -30 to -25 F | -31.7 to -34.4 C | Minneapolis/St .Paul, Minnesota; Lewistown, Montana |
| 4b | -25 to -20 F | -28.9 to -31.6 C | Northwood, Iowa; Nebraska |
| 5a | -20 to -15 F | -26.2 to -28.8 C | Des Moines, Iowa; Illinois |
| 5b | -15 to -10 F | -23.4 to -26.1 C | Columbia, Missouri; Mansfield, Pennsylvania |
| 6a | -10 to -5 F | -20.6 to -23.3 C | St. Louis, Missouri; Lebanon, Pennsylvania |
| 6b | -5 to 0 F | -17.8 to -20.5 C | McMinnville, Tennessee; Branson, Missouri |
| 7a | 0 to 5 F | -15.0 to -17.7 C | Oklahoma City, Oklahoma; South Boston, Virginia |
| 7b | 5 to 10 F | -12.3 to -14.9 C | Little Rock, Arkansas; Griffin, Georgia |
| 8a | 10 to 15 F | -9.5 to -12.2 C | Tifton, Georgia; Dallas, Texas |
| 8b | 15 to 20 F | -6.7 to -9.4 C | Austin, Texas; Gainesville, Florida |
| 9a | 20 to 25 F | -3.9 to -6.6 C | Houston, Texas; St. Augustine, Florida |
| 9b | 25 to 30 F | -1.2 to -3.8 C | Brownsville, Texas; Fort Pierce, Florida |
| 10a | 30 to 35 F | 1.6 to -1.1 C | Naples, Florida; Victorville, California |
| 10b | 35 to 40 F | 4.4 to 1.7 C | Miami, Florida; Coral Gables, Florida |
| 11 | above 40 F | above 4.5 C | Honolulu, Hawaii; Mazatlan, Mexico |

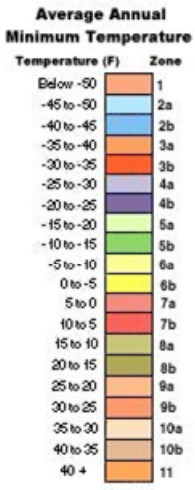


Montana

Maryland



North Carolina



# Architecture

4



# Section 4-1: General Architecture



## 4-1-00 Design Requirements

Excellence in design is a primary goal for all NIH design and construction projects. A commitment to quality by the design and management team is necessary to achieve this goal. Quality architectural and interior design can have a direct impact on improving the facility operating efficiency, attractiveness, life cycle economics, and ultimately, the productivity of the facility users. Design excellence does not add to project costs, but does require a balanced approach to design, which optimizes the functionality, aesthetics, quality and maintainability of facilities.

Designs should consider architectural compatibility with the NIH campus and NIH Master Plan objectives, functional requirements, economy of construction, energy conservation, interior and exterior details, and life cycle costs. Facility designs should address the needs of all users of the facility and enhance the lives of these users while providing the latest state-of-the art features to further the goals and objectives of the NIH throughout this century. For additional requirements specific to Research Laboratories and Animal Facilities see applicable Volumes of the Design Manual.

### A. General Health and Safety:

NIH, through DOHS, has developed a comprehensive occupational safety and health program to protect the safety and health of all employees. This includes the occupational work setting found in laboratories, animal handling activities, and mechanical support services. Safety and health regulations and guidelines require the use of engineering controls for worker protection, wherever possible, to minimize the potential for occupational exposure to hazards in the workplace. To be most effective, engineering controls for protecting occupational safety and health shall be designed into facilities for both new construction and renovated space. This proactive approach can minimize numerous common health and safety concerns in laboratory facilities. Facilities shall be designed for ease of maintenance. This is particularly important with regard to the specific containment devices (e.g., HEPA filter housings, HVAC systems, vacuum systems, autoclaves, etc.) designed for the facility.

These health and safety guidelines are to be incorporated, as appropriate, in facility specific construction documents by the A/E to ensure that health and safety protection is engineered into the design of any new or renovated facility and at the time of construction of the facilities.

While many of the requirements for health and safety engineering are incorporated in the DRM, it is impossible to cover all possible concerns. The A/E shall always consult with DOHS with regard to specific health and safety engineering requirements in the design of new construction and renovation projects.

## 4-1-10 Design Guidance

### A. Functional Design:

Floor plans should be simple and functional so as not to restrict flexibility. Permanent plan elements, such as mechanical shafts, stairways, and reinforced concrete vaults should be located to minimize their impact on functional use areas or future expansion of critical areas.

### A.1 Design Modules:

Modular design should be considered where appropriate. The building module used must consider the fire protection requirements which require that each level be subdivided into smoke zones as per the requirements of National Fire Protection Association (NFPA) Standards 101.

### A.2 Building Circulation:

Adequate circulation space should be provided at points of traffic congestion. Architectural features should emphasize overall circulation patterns and major entrances to departments. Circulation throughout the building should be efficient and direct without being restrictive. Clearly defined horizontal and vertical circulation routes for people, equipment, supplies, research animals, waste disposal and maintenance and repair activities are needed to ensure security and safety. Service corridor circulation, ghost corridor circulation between laboratories, and primary circulation patterns between department functions, laboratories, offices and animal or lab support spaces shall be clearly addressed early in the design process. The location of stairways and transition ramps shall be studied at connections between buildings with different floor-to-floor heights. Circulation should be made more efficient by:

- Avoiding confusing hallway systems and the extension of through corridors from department to department.

- Avoiding horseshoe shapes in major corridor systems that require excessive walking distances.
- Minimizing the use of single loaded corridors.
- Eliminating major corridors through elevator lobbies or through other areas that tend to concentrate circulating personnel.
- Locating vertical transportation element(s) so that they are easily visible from major entrances.

## A.3 Future Expansion Considerations:

Expansion of expensive existing scientific functions can often be coupled with relocation of lower cost functions. Placing scientific functions on outside walls with adjacent site space available for expansion also adds future flexibility. Corridor patterns can enhance circulation and flexibility. Adequate access to general circulation is needed for each department to facilitate visitor, patient, staff, and material traffic. Open plans, where feasible, allow easy scientific functional change. Floor plans that encircle a scientific function with permanent corridors, stairs, mechanical rooms, or other building elements difficult to relocate should be avoided.

Functional elements should be grouped in accordance with the following objectives. Where difficulties arise in the mutual accommodation of both of the following objectives, the objective stated below shall be given priority.

- Elements should be combined on the basis of functional adjacency requirements to facilitate better functional flow and reduced operating and staff costs.
- Elements with similar electrical, mechanical, and structural requirements should be combined to facilitate savings in construction costs.

Consistent with proper functional adjacency planning, soft functional areas (areas having minimal amounts of plumbing, special finishes, special mechanical features, and special power demands) should be placed between hard functional areas (areas having appreciable plumbing, special finishes, special mechanical features, and special power demands) to permit future growth of the hard functional areas by relocation of the less costly soft functional areas.

Column free functional areas should be ensured where possible while minimizing the use of transfer beams. A consistent column grid shall be provided in multistory facilities. Furthermore, it is recommended that columns be oversized and strengthen to accommodate additional floors. Electrical, mechanical, plumbing, and other support systems should be designed to permit modifications in support of scientific and medical functional changes with

the least life cycle cost and least disruption to the overall operations. Utility areas shall be located to ensure cost effective connections to site utilities and efficient distribution to functional areas. To enhance and improve utility distribution, stack similar utility areas vertically in multi-story facilities to the greatest extent possible. Provide adequate space for all required code safety clearances as well as for maintenance and repair operations within utility spaces. Additional information relative to utility requirements is contained in the Mechanical, Plumbing, Electrical and Communications Sections of the Design Manual.

## B. Building Massing:

Consideration should be given to the visual impact of any new structure, especially to a new addition on an existing building, and to the massing effect on surrounding views.

## C. Area Allowances:

The following calculations are for the purposes of design and construction and not to determine real estate space allocations for the purposes of charging rent.

## C.1 Gross Building Area:

The gross building area includes the total area of all floors, including basements, mezzanines, penthouses, mechanical and electrical spaces, and enclosed loading docks. Gross area is measured from the exterior surfaces of all enclosing walls except where the exterior wall surface overhangs the exterior window surface by 300 mm or more. In this case, the gross area is measured from a point one-half the distance between the exterior plane of the window glazing and the outermost plane of the wall. Shaft type elements such as atriums, stairs, unenclosed floor openings, elevators, escalators, dumbwaiters, lifts, mechanical and electrical shafts are included in the gross area for one floor only.

The gross building area exceeds the net area by a grossing factor. A range is given for these factors, depending on design choices for internal circulation patterns, interior partitions, utility distribution and mechanical equipment configurations.

Research Laboratories: A grossing factor of 1.54 to 2.00 is typical for research laboratories.

Animal Research Facilities: A grossing factor of 2.00 to 2.20 is typical for animal facilities.

Multiply the net floor area by the grossing factor to establish the projected gross building area. This gross area must be verified when actual plans are developed.

### C.2 Net Floor Area:

The net area of a space is measured from the interior surface of the walls that enclose the space. Exterior walls, interior partitions, columns, structural members, projections that lie within the walls of a room, and internal circulation within the space are excluded from the net floor area.

### D. Integration of Building Systems (IBS) Design:

Integration of Building Systems (IBS) concepts shall be applied to the design of all new biomedical and vivarium facilities and when warranted, to the design of other facility types based on size or complexity. IBS design involves the coordinated design of all elements of a building, integrating the functional, architectural, accessible, structural, mechanical, electrical, fire protection, energy, telecommunications and other features into a unified whole. All design elements are recognized as essential to a successful facility design and as such, are to be treated simultaneously and with equal weight. The primary objective of an integrated design approach is to achieve a building with optimum functionality, flexibility, adaptability, appearance and maintainability. Inherent in IBS design for biomedical and vivarium facilities are the principles that maintenance traffic and maintenance activities are minimized within functional areas through the careful location of equipment rooms and utility services. Equally important is the assurance of proper installation and maintainability of primary and distribution equipment through careful consideration and coordination of envelope space requirements. Utility system space planning must occur simultaneously with overall site and facility functional planning.

## 4-1-30 Design Document Requirements

### A. Architectural Plans (Design Development and Contract Documents)

Floor plans, sections, elevations, reflected ceiling plans, wall sections, roof plan, parapet or edge details, roof penetration details, interior elevations, finish schedules, door elevations, door schedule, door (jamb, head and thrush) details, window elevations, window schedule, window (jamb, head, and sill) details, equipment and casework layout, equipment and casework schedules, miscellaneous details, and cover sheet requirements shall be provided.

### B. Specifications (Outline and Detail Performance Specifications)

Outline specifications shall be developed at the design development stage and detail performance specifications shall be developed at the contract document stage.

### C. Cost Estimates (Systems and Quantity Takeoff Estimates)

Systems cost estimates shall be developed at design development stage and quantity takeoff estimates shall be developed at the contract document stage.

# Section 4-2: Exterior Architectural Elements



## 4-2-00 Design Requirements

### A. Exterior Walls

Exterior elevations (and exterior wall systems) shall be compatible with the styles of previously constructed permanent facilities of the campus and with the elements proposed in the NIH Master plan. To ensure compatibility, the physical features of the site and the character and style of any surrounding building(s) should be observed and documented by the design team. Colors, textures and forms of existing buildings or other site features must be considered when developing elevations for new construction. Elevations should be developed based on functional relationships and requirements and, where possible, should take advantage of existing and developed site assets

All building designs shall be presented to and receive approval from the Architectural Design Review Board (ADRB). The A/E shall coordinate ADRB submittal dates and requirements with the Project Officer. The A/E shall take into consideration the visual impact of any new structure, especially on an existing surrounding building(s). The A/E shall consider controlled access, monitoring features and physical security, and is required to contact DPSM for further direction in these areas during the planning and design stages.

### B. Operable Windows:

Operable windows are <u>not permitted</u> in NIH Research Laboratory and Animal Research Facility buildings.

## 4-2-10 Design Guidance

The design characteristics of exterior elevations and wall systems shall be evaluated for aesthetics, functionality, and cost effectiveness as their characteristics relate to the following:

- Exterior wall termination at the roof or the top of parapet walls (including penthouses).
- Construction and control joint locations, considering their impact on sterile areas, construction sequence, and building movement due to expansion and contraction.
- Corner conditions, especially material relationships at the intersections of vertical planes and the continuity of wall supports and flashings.
- Load transfer of the wall to the structure, including consideration of structural frame exposure and lateral wall supports.
- Watertight design, including sealant profiles, material adjacencies, and flashing configuration.
- Window placement relative to the wall, secondary connection requirements, material adjacencies, window washing, glass type and thickness, and life safety hardware.

## A. Exterior Walls:

Design and construction shall be based on standards, specifications, and publications for the products selected, i.e. masonry, curtain walls, metal panels, etc.

## A.1 Exterior Wall Compositions:

Exterior wall compositions shall be based on durability, thermal performance, vapor barrier requirement, and aesthetic requirements as they relate to the campus environment, cost, and in some cases, historic considerations.

## A.2 Exterior Building Materials:

Exterior cladding shall meet engineering standards with respect to sustainability, environment energy use, materials, and methods of construction. In selecting building materials, careful consideration must be given to all technical criteria and the requirement for high durability and minimal maintenance.

## A.3 Exterior Elements:

Mechanical, electrical, transportation, and equipment items that are located along the exterior of the facility shall be integrated into the design wherever possible, and per the pest management requirements. These elements include air intake/exhaust vents, exterior lights, utility connections, plumbing vents, fuel tank vents, liquid oxygen tanks, transformers, trash compactors, containers, and loading docks.

## A.4 Masonry:

Design and construction shall be based on standards, specifications, and publications for the products selected, including those by the American Society for Testing and Materials

(ASTM), American Concrete Institute (ACI), Building Stone Institute, Structural Clay Products Institute, Indiana Limestone Institute, Marble Institute of America, National Building Granite Quarries Association, National Concrete Masonry Association, Indiana Limestone Institute, Brick Industry Association, and the Portland Cement Association.

Exterior Walls Faced With Brick: If a building façade will be faced with brick or concrete masonry facing units, the backup across the cavity is preferred to be concrete masonry units (CMU). If cost/benefit analysis indicates substantial savings by using metal studs, utilize Brick Industry Association standards for wall durability. Anchorage of the brick facing shall be designed so as not to be subject to corrosion at the fastener to metal stud location. Assure the wall will not flex when subjected to location indicated wind loads.

## A.5 Curtain Walls:

Design and construction shall be based on standards, specifications, and publications for the products selected, including those by the ASTM, American National Standards Institute (ANSI), Aluminum Association (AA), Architectural Aluminum Manufacturing Association (AAMA), ACI, Metal Lath/Steel Framing Association, National Association of Architectural Metal Manufacturers, National Concrete Masonry Association, National Pre-cast Concrete Association, Portland Cement Association, Pre-cast Concrete Institute, Structural Clay Products Institute and Brick Industry Association.

## A.6 Wall Thickness:

Placement of the wall in relation to the structure impacts the construction cost, fenestration, shading, exterior materials, thermal performance, and method of assembly. Careful consideration shall be given during the design process to developing the optimum wall thickness that satisfies the above elements in the most effective manner.

# B. Thermal and Moisture Protection:

## B.1 Roofing Systems:

Roofing systems shall be compatible with structural framing systems, and provide a complete, readily repairable, waterproof assembly. The system should be durable, require minimal maintenance, and must provide the fire ratings and classifications required. Warranties shall be provided for various types of roof systems based on specific NIH input during design. Roofing systems shall be designed in accordance with the recommendations of the National Roofing and Contractors Association Roofing and Waterproofing Manual, Factory Mutual Guidelines, ASTM Specifications and Tests and Methods, National Bureau of Stan-

dards, and Underwriters Laboratories. On all new construction, the roofing system shall be designed for resistance to wind uplift forces.

The use of roof penetrations should be minimized to the greatest extent possible. Penetrations shall not be installed in valleys or near drains or scuppers. When roof mounted equipment is used, the equipment should provide the lowest profiles for the application used. The supports shall be designed for the equipment size and weight, for ease of a complete re-roofing process without disturbing the equipment, and for construction in a manner so as not to violate the waterproof integrity of the roofing materials. All roofs shall be designed with a positive slope to roof drains or gutters. Roof slope shall not be less than 21mm per meter. Consideration for future vertical expansion of the building should be incorporated in the roofing design on a project-by-project basis. All roofs shall provide for emergency overflow through the use of scuppers.

## B.2 Moisture Migration:

All new construction and project that substantially alter the building envelope shall be designed to prevent moisture migration and condensation of water vapor within the envelope assembly.

## B.3 Air Infiltration:

All new construction and projects that substantially alter the building envelope shall be designed to minimize air infiltration at locations separating the outdoors from interior conditioned spaces. Windows and doors shall be weather stripped. Exterior joints, cracks and holes in the building envelopes should be designed to be caulked, gasketed, weatherstripped, or otherwise sealed. All new construction and buildings that are substantially altered must include airlock vestibules or revolving doors at all primary entrances and exits to reduce infiltration due to stack draft effect.

## B.4 Thermal Resistance:

The thermal characteristics of single materials and composite design of exterior wall assemblies shall be obtained, designed, and comply per requirements as outlined in Chapter 6 HVAC in compliance with energy conservation requirements.

## B.5 Expansion Joints:

Horizontal and vertical expansion joints and relieving angles for cavity wall face brick shall be located, sized, and detailed in accordance with the manufacturer's recommendations.

## B.6 Joint Sealants and Caulking:

Joint sealants and caulking shall be applied throughout for thermal and moisture protection as architectural practice dictates, and as required for fire stopping penetrations per industry standards. For joint sealants and caulking requirements in containment areas, see Paragraph 4-7-00-C "Caulking and Sealants." The A/E shall also specify sealants and caulking as required for pest management. When sealing/caulking application is required for any of the reasons, the most stringent shall be applied. See Exhibit X4-2-A for pest management sealant requirements.

## C. Windows and Glazing:

All exterior windows shall be non-operable. All interior window sills shall be sloped, and all windows shall be caulked and sealed to ensure ease of cleaning and decontamination. Window systems shall use energy efficient glass. Consistent visual appearance on the exterior of the building shall be maintained by the type of window treatment selected. Appearance, function, heat gain, and loss air filtration, safety, structural requirements, suitability for the environment, operation and maintenance experience shall be considered.

Window treatments shall meet all functional and aesthetic needs and standards. Light tight treatments shall be provided in all spaces that require room darkening based on program needs, such as conference rooms, laboratories, etc. that may need to be darkened. If windows are provided in nonhuman primate areas, the room shall be capable of becoming light tight, accomplished through the use of adjustable shutters, blackout shades, or blackout panels. Integral devices within the window air space are preferred.

## C.1 Windows:

Fenestration shall be designed considering NFPA codes, heating, ventilation, and air-conditioning requirements, aesthetic appearance, and the comfort of all users of the facility. Window design and construction should be based on the standards, guidelines, and publications of the ASTM, ANSI, AA, Architectural Aluminum Manufacturing Association, National Institute of Testing and Standards, and the Steel Window Institute.

## C.2 Thermal Performance of Windows, Exterior Doors, Glazed Panels, and Skylights:

The use of glass shall be carefully studied in relation to energy conservation goals and building function. All new windows, glazed exterior doors, glazed panels and skylights shall be double glazed with a continuous thermal break. Condensation should not be apparent on glass when the indoor design temperature is $22^0$C at 30% relative humidity. All windows,

glazed exterior doors, glazed panels and skylights will have energy performance rating factors as evaluated in accordance with the National Fenestration Rating Council (NFRC) procedures to minimize air infiltration. The following average unit performance factors apply to NIH facilities.

## C.3 Glazing:

Glazing for windows, door glazed panel, skylights and curtain walls shall meet the requirements for energy conservation identified in DRM. All glazing designs should be evaluated for aesthetics, building function, energy conservation goals, shading characteristics, light transmittance, thermal characteristics, and reflectance. Low emissibity (Low-E) insulating glass shall be used unless other glazing types are shown to be more cost effective. Care must be taken to evaluate each building elevation individually. Glass sizes and thickness shall be based on wind loading and thermal conditions of the geographic area where the building is located.

Glazing for Impact Safety: Because of the size and shape of glazing in some locations, glass panels may be mistaken for a means of entry or exit and therefore may be subject to human impact. The requirements of ANSI Standard Z97.1, NFPA 80 and NFPA 101 shall be followed. Sill heights less than 760 mm above the finished floor must have an intermediate horizontal mullion, or suitable alternative, included in the fenestration or design at that height. If laminated glass is required for double glazed windows with a sill/stool less than 2 000mm above finish floor and for windows facing a courtyard, a laminated glass interior pane and tempered glass exterior pane shall be provided. If laminated glass is required for double glazed windows, it shall be provided for interior panes only.

## C.4 Provisions for Window Cleaning:

The need for window cleaning and maintenance, including replacement of glazing shall be considered during design. Provisions for window cleaning equipment must be included in the design for all facilities.

## C.5 Windows for Historic Buildings:

Projects affecting windows of historic building shall comply with the Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitation Historic Buildings and the State Historic Preservation Office (SHPO). The A/E shall coordinate the design requirements with the NIH Historic Preservation Coordinator.

# D. Loading Docks

## D.1 Shipping and Receiving Areas:

Shipping and receiving marshalling space should be adjacent to the dock. The dock area also requires an office and telephone for the dock manager, toilet facilities, and an area to house vending machines. Vending areas must be designed to promote proper cleaning and sanitation. Materials used throughout these spaces should be durable enough to withstand high personnel use and regular cleaning activities. The loading dock berths, dock area and adjacent functional areas should be securable and should be designed to minimize the harboring of pests.

## D.2 Overhead Protection:

Loading dock designs should allow materials to be protected from inclement weather conditions, while loading and unloading vehicles. Any overhangs or canopy projections in the vicinity of the loading dock must be of a sufficient height so as to provide necessary truck clearances, including the removal of refuse containers. Review of these design features by the Division of Environmental Protection is required prior to finalizing design.

## D.3 Loading Dock Berths:

A minimum of two loading dock berths per building should be provided. Some buildings require additional berths depending on the function of the facility. For facilities housing animals, a dedicated animal berth that is visually protected for security should also be provided in addition to the two berths previously identified. This berth must be physically segregated from other dock berths and dock support functions. This includes vehicle docking and materials/supplies staging. Loading dock berths should be equipped with hydraulic load levelers, and at least one should be equipped with a hydraulic scissors lift capable of carrying a 1,016 kg load as a minimum.

## D.4 Dock Protection:

Protective metal dock plates at the edge of the dock should be provided. Commercial grade dock bumpers (shock absorbing design, manufactured of pliable rubber) should be mounted under load levelers. Barriers that can prevent a truck from damaging the load leveler when backing to the leveler should also be provided.

## D.5 Service Ramp:

A ramp with a gentle grade should be provided near the loading berths to allow small deliveries via lightweight equipment such as two wheeled hand trucks or four wheeled platform trucks that allows personnel to reach grade from the loading dock

## D.6 Telephone/Doorbell:

A doorbell and “house” telephone located on the exterior of the loading docks shall be provided

## D.7 Dock Wash down:

Hose bibs for loading dock shall be provided for wash down and cleanup activities.

## D.8 General Concrete Apron for Loading Docks:

Loading docks shall be provided with concrete aprons of sufficient length and width to accommodate 23 m³ capacity compactor and open top containers or storage trailers.

## D.9 Storage Requirements:

Provide and install adjustable height bi-level metal shelving with lipped edges and corrosion resistant coating for spill containment to provide segregated storage of wastes of various compatibility classes. This shall not be located adjacent to the animal loading dock.

## E. Waste Management Areas:

Separate spaces should be provided within the dock area for holding and disposing of medical pathological waste, hazardous waste, radioactive waste, mixed waste, general waste, and recycling waste. Waste should not be staged for removal inside the receiving area of the loading dock. The dock entry points used for materials receiving or personnel must be isolated from the solid waste compacting, handling and storage operations, as solid waste operations can be attractive to pest species that are invasive to the facility.

## E.1 Trash Dumpsters and Compactors:

A separate area for a minimum of one dumpster shall be programmed within the loading dock space. This area shall be constructed of a 200 mm thick reinforced concrete pad 9 150 mm minimum in length. The dumpster shall not block the loading dock, but access for disposal of trash to the dumpster shall be directly from the loading dock.

All new buildings shall be provided with a minimum of two 23 m³ self enclosed compactors or equivalent equipment for collection of cardboard to be recycled and general trash. Compactors shall be sited and designed to facilitate proper use and cleaning.

Dumpsters and compactors shall be provided with electrical power connections and hydraulic systems per manufacturers recommendations.

Smaller Buildings at Offsite Locations: Smaller buildings will not always require use of compactors based on occupancy and square footage. Smaller building shall allow loading dock space for two front end containers to provide for cardboard recycling and general trash disposal

### E.2 Waste Management Rooms:

See Section 1-9 Environmental Management/Radiation Safety. The dock entry points used for materials receiving or personnel shall be isolated from the solid waste compacting, handling, and storage operations, as solid waste operations can be attractive to pest species that are invasive to the facility.

### E.3 Chemical Waste and Radiological Waste Storage Room:

See Section 1-9 Environmental Management/Radiation Safety. This room shall not be located adjacent to the animal loading dock.

### E.4 Recycling Storage Room:

See Section 1-9 Environmental Management/Radiation Safety. This room shall not be located adjacent to the animal loading dock.

### E.5 Medical Waste Cold Boxes:

See Section 1-9 Environmental Management/Radiation Safety. MPW Cold Boxes shall not be located adjacent to the animal loading dock.

## 4-2-10 Design Information

### A. Thermal Performance of Windows, Exterior Doors, Glazed Panels, and Skylights:

### A.1 NIH Campus, Bethesda, MD, including surrounding areas and Raleigh-Durham, North Carolina Facilities:

Thermal performance for windows, glazed exterior doors, and glazed panels shall be 2.271 W/($m^2$ K) (0.40 U). Thermal performance for skylights shall be 2.555 W/($m^2$ K) (0.45 U). Solar heat gain for all fenestration types shall be 3.123 W/($m^2$ K) (0.55 U). Products with a higher visible transmittance to maximize daylight and view should be selected. Products with an air leakage rating of 0.30 or less cfm/square foot should be selected.

## A.2 Hamilton, Montana Facilities:

Thermal performance for windows, glazed exterior doors and glazed panels shall be 1.987 W/($m^2$ K) (0.35 U). Thermal performance for skylights shall be 2.555 W/($m^2$ K) (0.45 U). Solar heat gain is not applicable. Products with a higher visible transmittance to maximize daylight and view should be selected. Products with an air leakage rating of 0.30 or less cfm/square foot should be selected.

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| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| Doors: | FRP Doors shall be used for both interior and exterior door in animal care facilities | N/C | N/C | JS-5/8 | Vivarium areas only |
| | Seal all penetrations in doors | N/C | N/C | JS-5/8 | |
| | Seal all door hinge plates (not at pin) to include piano hinges | N/C | N/C | JS-5/8 | |
| | Seal door frame and wall board interface | JS-5/8 | JS-5/8 | JS-5/8 | |
| | Seal view panel frames (around glass even if gasketed) | N/C | N/C | JS-5/8 | |
| | Seal around lock sets and door frames | N/C | N/C | JS-5/8 | |
| | All door frames must have plastic latch boxes installed to reduce access into the hollow frames | N/C | N/C | JS-5/8 | |
| | Seal door thresholds to the floor | JS-1 | JS-1 | JS-5/8 | |
| | Caulk door protection/kick plates and tapered door guards to doors | N/C | N/C | JS-5/8 | |
| | Caulk gaps around door magnet latch at head of door and frame | N/C | N/C | JS-5/8 | |
| Cabinetry/Shelving: | Seal openings in the base of floating tables where the support feet mount | N/C | JS-5/8 | JS-5/8 | |
| | Seal openings in table legs where the support feet mount | N/C | JS-5/8 | JS-5/8 | |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal all cabinets where they contact dissimilar materials | N/C | JS-5/8 | JS-5/8 | cabinets need to be closed boxes |
| | Seal all counter tops where they contact with other sur-faces | N/C | JS-5 / JS-7 | JS-5/8 | Depends on sequence and finish |
| | Seal around all shelf support brackets where they con-tact the shelves and are mounted to the walls | N/C | N/C | JS-5/8 | This is for specialty shelving used in laboratories. |
| | Seal rails used for animal caging at the wall juncture | N/C | JS-5/8 | JS-5/8 | |
| | Seal rails used for shelving at the wall juncture | N/C | JS-5/8 | JS-5/8 | |
| | Seal tops and bottoms of all wall mounted shelving brackets | N/C | JS-5/8 | JS-5/8 | Usually a plug however should be sealed in addi-tion to. |
| | Seal all gaps and openings in stainless steel racks | N/C | N/C | JS-8/12 | ABSL 3 equipment, usually seen in aquatic rooms |
| | Seal covers between shelf standards | N/C | N/C | JS-8 | |
| | Seal all cabinets where they contact one another | N/C | JS-5/8 | JS-5/8 | |
| | Seal peninsula shelving support at countertop and at ceiling | N/C | JS-5/8 | JS-5/8 | |
| Walls/Floors/Ceilings: | Seal around all wall guards | N/C | JS-5/8 | JS-5/8 | Brackets/fasteners shall be installed tight to wall. |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal all penetrations on the top and bottom of slab | JS-10 | JS-10 | JS-10 | To include but not limited to HVAC, plumbing, and electrical penetrations, and like penetrations through interstitial space. |
| | Seal around all corner guards | N/C | JS-5/8 | JS-5/8 | Brackets/fasteners shall be installed tight to wall. |
| | Seal around all door bumpers | N/C | N/C | JS-5/8 | Brackets/fasteners shall be installed tight to wall. |
| | Seal around all kick plates | N/C | N/C | JS-5/8 | Brackets/fasteners shall be installed tight to wall. |
| | Seal top of epoxy trim strip and vinyl sheet flooring at wall | N/C | N/C | JS-5/8 | Recommend feathering epoxy cove base to flat surface, e.g. not at grout line (see line 48) |
| | Seal all ceiling access panels (if not 100% gasketed) | N/C | N/C | N/C | |
| | Seal the perimeter of all suspended acoustical ceiling frames at the wall juncture | N/C | JS-5/8 | N/C | |
| | Seal all interior window frames (including gasketed areas) | N/C | JS-5/8 | JS-5/8 | Caulk bead should be sloped to promote cleaning |
| | Seal all wall surface-mounted mounting plates | N/C | JS-5/8 | JS-5/8 | This applies to exposed mounted brackets. The use of caulk at these brackets is as follows: 1) If the bracket or wall mounted fixture is easily re-movable, then caulk is not required, 2) If the brackets are permanently affixed to wall, then joints should be caulked. Each bracket should be examined for requirement of caulk in case by case basis. |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal all floor surface-mounted mounting plates | N/C | JS-7 | JS-5/8 | This applies to exposed mounted brackets. The use of caulk at these brackets is as follows: 1) If the bracket or wall mounted fixture is easily re-movable, then caulk is not required, 2) If the brackets are permanently affixed to wall, then joints should be caulked. Each bracket should be examined for requirement of caulk in case by case basis. |
| | Seal all ceiling surface-mounted mounting plates at dry-wall ceilings | N/C | JS-5/8 | JS-5/8 | This applies to exposed mounted brackets. The use of caulk at these brackets is as follows: 1) If the bracket or wall mounted fixture is easily re-movable, then caulk is not required, 2) If the brackets are permanently affixed to wall, then joints should be caulked. Each bracket should be examined for requirement of caulk in case by case basis. |
| | Seal all wall surface-mounted cover plates | N/C | JS-5/8 | JS-5/8 | |
| | Seal all floor surface-mounted cover plates | N/C | JS-5/8 | JS-5/8 | |
| | Seal all ceiling surface-mounted cover plates | N/C | JS-5/8 | JS-5/8 | |
| | Seal and cap the tops of all CMU walls | N/A | N/A | N/C, no foam | Vivarium areas only; recommend sheet rock (caulk with JS-5/8) or CMU cap block |
| | Seal around all metal cap strips on the top edge of epoxy cove base | N/C | N/C | JS-5/8 | |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal vinyl baseboard molding, at the top bottom and terminate at door frame | N/C | JS-5/8 | JS-5/8 | |
| | Seal control joints in walls | N/C | JS-5/8 | JS-5/8 | |
| | Seal control joints in ceilings | N/C | JS-5/8 | JS-5/8 | |
| | Seal control joints in floors | JS-1 | JS-1 | JS-1 | Not visible to room - beneath floor |
| | Seal all crash rails, guard rails stand offs, and door rollers mounting brackets | N/C | JS-5/8 | JS-5/8 | |
| | Seal joints between walls of dissimilar materials | JS-5 | JS-5/8 | JS-5/8 | |
| | Seal space in wall penetrations, including inside sleeves, collars, and surrounding construction | Stuff Min Wool | Stuff Min Wool Seal JS-4/JS-5 | Stuff Min Wool Seal JS-4/JS-5 | |
| HVAC: | Seal all duct work that penetrates the wall envelope | N/C | JS-5/8 | JS-5/8 | |
| | Diffusers/grill joints in hard ceilings should be sealed | N/C | JS-5/8 | JS-5/8 | |
| Plumbing: | Hot water line insulation should be wrapped in aluminum and the seams and ends of the insulation caulked and sealed | N/C | JS-12 | JS-12 | This applies for steam lines (e.g. autoclaves). |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal at vacuum pass-through | N/C | JS-7 | JS-7 | |
| | Seal all cracks in foam rubber water line insulation | N/C | JS-7 | JS-7 | |
| | All flat escutcheon plates and support standoff brackets for animal water systems should be sealed | N/C | JS-5/8 | JS-5/8 | |
| | Seal plumbing to surface where a gap of 6 mm to 9mm of less exists | N/C | JS-5/8 | JS-5/8 | |
| | Seal all plumbing escutcheon and cover plates at the wall and pipe junctions | N/C | JS-5/8 | JS-5/8 | |
| | Seal around sprinkler collars | N/C | JS-5/8 | JS-5/8 | |
| | Seal all piping that penetrates the wall envelope | N/C | JS-5/8 | JS-5/8 | |
| Electrical: | Seal electrical conduit to surface where a gap of 6 mm to 9mm or less exists | N/C | JS-5/8 | JS-5/8 | |
| | Joints in power strips mounted on casework | N/C | N/C | JS-5/8 | *Assuming power strip is surface metal raceway - surface metal raceway is NOT allowed in any ABSL areas, nor in BSL3 areas. |
| | Conduit tight to wall shall be sealed (concealed) | N/C | JS-5/8 | JS-5/8 | Tight to wall conduit needs sealant on both sides |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal the perimeter of all electrical panels | N/C | JS-5/8 | JS-5/8 | * Panelboards in BSL2 spaces do not require sealing - if done, recommend with gasket only. Locating panelboards within ABSL areas should be avoided and should never be placed with actual BSL3 space. If required within ABSL space, gasketing and sealing is required. Sealing/caulking of cover plates in BSL2 is not required. |
| | Seal joints between ceiling and light fixtures in hard ceilings | N/C | JS-5/8 | JS-5/8 | Recessed lights shall be gasketed. |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal perimeter of device boxes to adjacent drywall/CMU. Wire within conduit shall be sealed also. | N/C | N/C | JS-5/8 | For ABSL-2 vivarium facilities: All device boxes shall be cast type. Where device boxes and conduits are recessed mounted, the box to the adjacent wall, ceiling or floor surface shall be sealed. All wiring shall be provided in either threaded RGS, IMC (when recessed), or electrical metallic tubing (only when recessed and with compression fittings). Once wiring is installed, the wiring shall be surrounded by a one inch barrier of silicone caulking around the conductors within the device box hub. Gasketed device cover plates shall be used. Where device boxes and conduits are surface mounted, and where the device box meets the wall, ceiling, or floor surface, a continuous bead of silicone caulk shall be provided. Non-recessed conduits are then required to be threaded RGS on minimum ¾" standoffs, or if also surface mounted, both sides of the conduit shall be sealed to adjacent surfaces with silicone caulk. This prevents vermin harborage in and transmission through the electrical distribution systems. |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal perimeter of device boxes to adjacent drywall/CMU. Wire within conduit shall be sealed also. | N/C | N/C | JS-5/8 | For ABSL3 vivarium and laboratory facilities: All device boxes should be cast type. Where device boxes and conduits are recessed mounted, the box to the adjacent wall, ceiling or floor surface shall be sealed. All wiring shall be provided in threaded rigid galvanized steel (RGS) or intermediate metal conduits (IMC) (only when recessed). All device boxes shall be cast type. Once wiring is installed, the wiring shall be sur-rounded by a one inch barrier of silicone caulking around the conductors within the device box hub. Gasketed device cover plates shall be used. Where device boxes and conduits are surface mounted, and where the device box meets the wall, ceiling, or floor surface, a continuous bead of silicone caulk shall be provided. Non-recessed conduits are then required to be on minimum ¾" standoffs, or if also surface mounted, both sides of the conduit shall be sealed to adjacent surfaces with silicone caulk. This provides for a gas tight electrical installation allowing decontamination of the BL3 space, and prevents vermin harborage in and transmission through the electrical distribution systems. |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| Equipment: | Seal all fixed equipment that is within 38 mm or less from a ceiling | N/C | JS-5/8 | JS-5/8 | Backer rod then sealed |
| | All sinks need to be caulked or sealed if they contact other surfaces, including mounting and support brackets | N/C | JS-5/8 | JS-5/8 | |
| | Large gaps, behind the back splash should be filled in with foam cord and caulked in place. | N/C | JS-5/8 | JS-5/8 | |
| | Seal all gaps and openings in secured /fixed equipment | N/C | N/C | JS-5/8 | May hinder function of equipment - Review on a case by case basis |
| | Seal gaps that exist between stainless steel sheet metal in all cage washes | N/C | JS-12 | JS-12 | |
| | Seal gaps that exist between stainless steel sheet metal in all tunnel washers | N/C | JS-12 | JS-12 | |
| | Seal gaps that exist between stainless steel sheet metal in all rack wash equipment | N/C | JS-12 | JS-12 | |
| | Seal around frames and holes inside of fire extinguisher boxes | N/C | JS-5/8 | JS-5/8 | Some doors have hollow channel in access doors. Seal access door frame channels and glass cover where no clips are present. |
| | Seal around the metal rod hangers used to hold the exhaust hoods where they penetrate the drop ceiling | N/C | JS-5/8 | JS-5/8 | |

| Group | Description | Non-Sensitive | Sensitive/Special Areas | | Comments |
|---|---|---|---|---|---|
| | | Non-BSL | BSL-2 | BSL3/ABSL3 | |
| | | Sealant Type | | | |
| | | | | | |
| Sealant Types: | JS-1 Arch Urethane Seal<br>JS-4 Si. (Color: W, A, C)<br>JS-5 Siliconized Acrylic Latex 50 yr Warrantee | JS-6/7 FDA San.Si (Clear)<br>JS-8 FDC Siliconized Acrylic (50 yr Warrantee)<br>JS-10 - Non-Halogenated Latex- Based Elasto-metric Sealant | | | JS-9 Ex. Foam (B)<br>JS-12 Aluminum Finish<br>N/C - No Caulk |
| | | | | | |
| | Seal or caulk wall mounted heating/air conditioner unit casework and utility penetrations | N/C | JS-5/8 | JS-5/8 | |
| Fixtures: | Stainless Steel Equipment | N/C | JS-12 | JS-12 | |
| | Toilet | JS-5 | JS-5/8 | JS-5/8 | |
| | Sink Faucet | JS-5 | JS-5/8 | JS-5/8 | |
| | Wall Hung Equipment | N/C | JS-5/8 | JS-5/8 | |

It is recommended that the NIH Project Officer responsible for the construction project contact the Community Health Branch (CHB) for guidance on caulking, sealing and pest management related issues prior to the commencement of a construction project. The list above contains the majority of areas to be caulked or sealed to reduce pest harborage, but is by no means finite, and should be used as a supplement to other joint sealing specifications.

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# Section 4-3: Interior Architectural Elements



## 4-3-00 Design Requirements

### A. Doors

#### A.1 Hollow Metal Doors:

Doors into biomedical laboratories along a service corridor shall be 1 200 mm (42”) wide with 900 mm active leaf and 300 mm inactive leaf. The door along the personnel corridor shall be a single leaf 900 mm door. In the event no service corridor is planned, a double leaf door along the personnel corridor is strongly recommended. DFM permits the use of manual flush bolts on inactive leaf of laboratory doors (normally only permitted in unoccupied areas like mechanical rooms).

Doors shall be minimum 2 100 mm high. In laboratories where the use of larger equipment is anticipated, wider/higher doors shall be considered. Laboratory doors shall be recessed and swing outward in the direction of egress. Door assemblies shall comply with all appropriate codes. Hollow metal doors are not permitted in animal housing areas.

#### A.2 FRP Doors:

Doors in animal research facility animal holding areas shall be provided with fiberglass-reinforced polyester (FRP) doors. Doors shall be sized to easily accommodate passage of cages, racks, and other large mobile equipment. Use automatic doors in high traffic areas. To accommodate personnel and equipment needs, provide two leaf doorways with differing leaf sizes using leaves sized at 1 100 mm and 765 mm. Where only a single leaf is required, minimum width shall be 1 100 mm. Minimum clear height shall be 2 200 mm or as required for clear cage passage.

FRP doors shall also be provided for areas subject to impact or abuse in biomedical laboratories.

### A.3 Doors that are Not Permitted:

Pocket doors, sliding doors, and accordion doors are not permitted in NIH biomedical laboratories or animal research facilities.

### A.4 Life Safety Provisions per DFM:

Where doors are required to be fire rated, the A/E shall specify the appropriately rated UL label door and frame. All fire doors and frames shall be hollow metal. Fire rated wood doors are not permitted. All paired fire rated doors shall be provided with astragals. Power assisted fire rated doors shall be provided with an interconnection with the fire alarm system to deactivate the power to the door operator when the fire alarm activates.

Doors that are a part of a required means of egress to the exterior of a building that are also used as part of a means of egress (exit) shall be readily operated from the interior of the building. The determination on whether the device shall be fail safe or fail secure will be made by the DP and DFM, DRS, with input from the Users.

## 4-3-10 Design Guidance

### A. Doors

### A.1 Door Material:

Doors that are heavily used have a reduced life expectancy and require frequent repair and maintenance. Doors shall be equipped with the following:

- Bumper rails.
- Kick plates.
- Magnetic hold open devices.

All doors within the facility not required to be fire rated, as well as all perimeter exterior doors into any building that houses animals, shall be fiberglass reinforced polyester (FRP) doors. Doors shall conform to the NIH Division 8 Specification Section “Fiberglass Reinforced Polyester (FRP) Doors.”

### A.2 Door Pulls and Hinges for Interior FRP Doors:

Specific door pulls shall be provided wherever FRP doors are specified within the interior of the animal facility. This recessed door pull features a “clean room design” with profiles and

surfaces that are designed not to hold water from frequent washings. Each door leaf shall be equipped with a continuous, heavy duty 14 gauge stainless steel hinge with a 6.35 mm stainless steel pin. Geared hinges and field painting is not permitted

## A.3 FRP Door Frames:

Door frames shall be completely filled with grout or other inert material to prevent harboring of pests and sealed to surrounding construction

## A.4 Vision Panels:

Vision panels shall be provided in the active leaf of all laboratory doors, double doors, and other doors as required by program requirements. Depending on program requirements, vision panels may require light tight covers

## A.5 Door Hardware:

Laboratory doors are considered high use doors. All hardware shall be appropriately specified to withstand this type of use. Light commercial grade hardware shall not be specified. All appropriate hardware to meet security, accessibility, and life safety requirements shall be provided. Doors shall be fitted with door protection. Laboratory door hardware and keying shall comply with requirements the Division of Public Safety (DPS) Locksmith Section and DPSM.

## A.6 Card Access:

Provide card access readers for doors as required by program and NIH DPSM requirements.

## A.7 Security Access:

Coordinate with DPSM fir specific security requirements.

## A.8 Door Keying Systems, Cores, Locksets and Hardware:

Door keying throughout NIH facilities has been standardized to the greatest extent possible to facilitate rapid changes when occupants or missions change within a building or area. For additional information related to door hardware and security, coordinate with DPSM.

- Reviews of Key System: DPS Locksmith Section provides specific information on the keying requirements for all NIH projects.
- Key System and Keying: Final keying requirements shall be determined by the NIH locksmith and incorporated into the project by the A/E. The key and lock system shall be

based on several levels of master keys. Grand masters and great-grand masters shall be provided for functional zones and modules. The NIH shall be provided with the following keys: 1 master key; 2 change keys per cylinder and 1 extra blank for each lock; and a minimum of 500 key blanks and key biting chart.

- Mortise Locksets and Lockset Trim: All interior doors shall be equipped with mortise locksets unless fire codes dictate otherwise. Mortise locksets shall be Series 1000, Grade 1, to be compatible with existing locksets, as directed by Locksmith. All lockset trim shall have lever handles with a return to within 13 mm of the door face. The selected lockset trim shall match the NIH standard lockset trim and shall be approved by DPS Locksmith Section.
- Lockset Cylinders: All lockset cylinders for new facilities at the NIH shall be a high security type as required by DPS Locksmith Section. For renovations, all locks shall be keyed into the same system used on the existing building. Key-in-knob hardware is not permitted at the NIH.
- Pin: The number of pins provided in high security cylinders shall vary by manufacturer. The number of pins standard for the manufacturer shall be provided by DPS Locksmith Section.
- Exit Devices: The A/E shall specify exit devices that are used throughout NIH facilities. Final selection shall be verified and approved by DPS Locksmith Section.
- Closers: Closers in the vivarium shall not impede the clear width and height of door opening. Verify all requirements with DPS Locksmith Section. The A/E shall take precautions to coordinate ADA requirements for required minimum force to be applied, which is less than laboratory pressurization reactions on the door (5N).
- Cores: Temporary construction cores shall be provided during the construction period and shall be removed by the construction contractor when directed

## B. Interior Partitions

### B.1 Interior Drywall Partitions:

Where metal stud and drywall partitions are acceptable for use, studs of at least 18 gauge, 90 mm in depth, and spaced at 400 mm on center shall receive first consideration for use. Where NFPA standards and construction drawings permit stopping full height partitions at the ceiling suspension system, provide lateral bracing at the top of all partitions that exceed 2 850 mm in height. Partitions of lesser overall height shall be securely anchored to a stable ceiling suspension system. The top track of the stud system shall be fastened to the ceiling suspension components at 600 mm on center with #12 self cutting screws. For partitions exceeding 2 850 mm, lateral bracing shall be provided at a 45° to 60° angle above the ceiling at a maximum spacing of 1 800 mm. For a brace length of up to 1 800 mm, provide

a 30 mm x 30 mm x 3 mm steel angle. Bracing locations shall be coordinated, prior to installation, with all other items and services that shall be located above the ceiling.

To provide greater flexibility for future installations of wall hung shelves, bookcases and cabinetry, provide internal reinforcing when the partitions are constructed. Provide 100 mm wide, at least 1.33 mm metal gauge sheet metal strips, placed horizontally on both sides of the studs for the full length of the partition. Anchor the strips to each stud with two #12 screws. Install the top edge of these metal strips at the following heights:

- 150 mm and 300 mm above the finished floor to provide a fastening opportunity for vertical support standards for the utility ledge.
- 765 mm above the finished floor to provide a fastening opportunity to anchor the steel angle at the back edge of the seated height countertops.
- 914 mm above the finished floor to provide a fastening opportunity to anchor the steel angle at the back edge of the standing height countertops.
- 1 200 mm above the floor to provide a fastening opportunity to anchor the wire mold.
- 1 700 mm above the floor to provide a fastening opportunity for the bottom angle that supports wall cabinets. This assumes that the bottom of the 800 mm tall wall cabinets shall be located 1 725 mm above the floor, and the cabinets shall be supported as described in the Anchorage of Shelving and Wall Cabinets paragraph below. This location also allows shelf bracket vertical support standards to be anchored when it is not possible to anchor them to metal studs
- 2 500 mm above the floor to provide a fastening opportunity to anchor the steel angle at the top of the 800 mm tall wall cabinets. This location also allows shelf bracket vertical support standards to be anchored when it is not possible to anchor them to metal studs.
- Finish drywall partitions to level 5.
- High density, high impact, water resistant type 6 gypsum wallboard in vivariums to withstand impacts of cages, carts and racks, and shall be moisture proof or resistant.
- Wire studs in partitions are not permitted.

## B.2 Gypsum Wallboard (GWB):

High density, water resistant GWB is an appropriate wall material and shall be evaluated on the basis of program and cost requirements. If GWB is selected as the wall material, bumper guards/rails shall be provided at multiple heights on all walls in corridors and animal holding rooms to prevent damage from cages, racks, and handcarts.

## B.3 Concrete Masonry Units (CMU's):

If concrete masonry is selected for the wall finish material, it shall be sealed with two coats (minimum) of epoxy block filler before the application of epoxy finish coating systems. Failure to provide this surface preparation will result in a porous, pinhole filled surface that is difficult to clean. All CMU joints shall be tooled flush to avoid the collection of dirt prior to the application of block filler to eliminate pinholes. CMU walls shall be painted with at least two finish coats. Corners shall be rounded CMU in animal care areas and where material handling devices are used (pallet trucks, etc.).

## B.4 Concrete Walls:

Concrete walls shall be constructed so as to prevent cracking. Surface preparation shall result in a nonporous, smooth surface that is easy to clean. The concrete wall shall be sealed with two coats (minimum) of epoxy before the application of epoxy finish coating systems. The finish coat or system applied to the substrate shall be smooth, easily cleaned, and minimize pest access. Corners shall be rounded in animal care areas and where material handling devices are used (pallet trucks, etc.).

## B.5 Bumper/Wall Guards and Corner Guards:

Extensive use of bumper/wall guards and corner guards is required throughout an animal facility regardless of the wall construction to minimize impact related wall damage. Only solid materials that can withstand moisture and cleaning shall be specified. Solid shapes shall be provided. Hollow products are not permitted as the voids cannot be cleaned and provide harborage for pests.

Wall guards shall be designed to protect door frames wherever possible by returning the ends into the frame. Guards shall be provided in a high-low configuration in all corridors and cage wash areas to protect walls from damage by mobile equipment of various sizes. Rounded, stainless steel corner guards shall be used at all external corners in corridors, animal rooms, and other spaces subject to impact damage. Wall and corner protection shall be sealed to the mounting surface with proper sealant at time of installation.

# Section 4-4: Interior Finishes



## 4-4-00 Design Requirements

The interior design for a facility should be developed as a complete and coordinated part of the building design, expressing both the functional and aesthetic needs of the user. Finish materials are what the user and visitor: sees, touches, and walks on and therefore produce an immediate impact. All interior components and their related construction details, finishes and products, shall be based on the anticipated use, engineering limitations, fire and other health and safety requirements, applicable codes and regulations, life cycle costs, housekeeping and maintenance costs, durability, aseptic characteristics, and the appropriateness of the particular material or combination of materials to the environment being created.

Color selection is an important element of the building's interior and exterior design. Color selection should be coordinated with the quality and quantity of light provided in each space. Colors and patterns should be selected with regard to their effect on the maintainability and function of the space as well as with regard to their impact on the health and welfare of the people who will be using the space. The range of interior and exterior colors should be made from a limited pallet to facilitate maintenance and coordinate with all finishes, furnishings and accessories. Lighter colors with improved light reflectivity characteristics should be used to the greatest extent possible to improve functional lighting levels. Matte surface finishes should be provided where glare from a high gloss finish would be functionally disruptive. Color selections shall be made by the designer and incorporated and coordinated throughout the contract documents for the project.

The Interior Designer is required to make selections of finishes, materials, furniture and products from the GSA Federal Supply Schedule. Current GSA contract schedules must be verified with each manufacturer prior to specifying items. The designer must consider the expiration dates of those contracts to assure availability of the product at the anticipated time when product ordering is to occur. Contract Documents shall be developed to require a submittal of all manufacturers' information about the installation instructions, flammability

ratings, static and acoustic characteristics, and recommended maintenance and stain removal techniques for all interior finishes and materials.

Materials selected for the finishes of laboratories shall be durable, smooth, and easily cleaned, provide ease of maintenance, minimize pest access, and contribute to the creation of a comfortable, productive, and safe work environment.

Materials for laboratory finishes shall be as resistant as possible to the corrosive chemical activity of disinfectants and other chemicals used in the laboratory. Finishes shall be sealed to provide a positive barrier against the harborage of pests and vermin. Structural and construction joints shall be detailed to be easily cleaned and decontaminated

## A. Ceilings:

Ceilings such as washable lay-in acoustical tiles (mylar face with smooth surface, vinyl face or equivalent) with a square edge (not tegular) on a non-concealed spline shall be provided for most laboratory spaces. Ceiling heights shall be a minimum 2 850 mm in laboratory and laboratory support spaces and a minimum of 2 440 mm in administrative spaces. Gypsum board with epoxy paint ceilings, equipped with access panels, shall be provided in glassware washing and autoclave rooms, where the potential for a high moisture level exists. Access panels shall be fitted with gaskets that seal the door when closed and also the flange around the panel lip where it meets the ceiling. Open ceilings are acceptable provided minimal ducting and piping are present, and all exposed surfaces are smooth and easily cleaned.

## B. Walls:

Wall surfaces shall be free from cracks, unsealed penetrations, and imperfect junctions with ceiling and floors. Materials shall be capable of withstanding washing with strong detergents and disinfectants and be capable of withstanding the impact of normal traffic. Many areas within an animal facility are subject to water daily, including impact damage from hose streams. Walls in these areas shall be constructed of concrete, concrete block, or surfaced with a heavy duty, impenetrable veneer, such as fiberglass reinforced panels (seamless).

## C. Flooring:

Floors shall be designed to accommodate different types of wheeled conveyances and shall be devoid of abrupt changes in elevation. Avoid raised thresholds, steps, and ramps in circulation areas. Consideration shall be given to radiographic electrical floor ducts. The A/E selections shall be influenced by an understanding of the specific use of the particular area. When selecting floor finishes the A/E shall consider:

- Durability and permanence.
- Functionality of room/space.
- Maintenance.
- Floor flatness ($F_F$) and floor levelness ($F_L$): Numbers shall be specified when the installations of finish materials, functional conditions, or equipment dictate tight control of concrete slab substrates.
- Interstitial space flooring system shall be addressed for noise transmission, water–tightness and possible self leveling sealants.

### C.1 Biomedical Laboratory Floor and Base Materials:

Floor materials shall be nonabsorbent, skid proof, resistant to wear, and resistant to the adverse effects of acids, solvents, and detergents. Materials may be monolithic (sheet flooring) or have a minimal number of joints such as vinyl composition tile (VCT) or rubber tile. Floor materials shall be installed to allow for decontamination with liquid disinfectants and to minimize the potential spread of spills. The base for VCT or rubber tile may be a 100 mm high easily cleaned vinyl or rubber material.

### C.2 Animal Research Facility Floor and Base Materials:

Floors shall be smooth, durable, moisture proof, nonabsorbent, and slip resistant and resistant to the adverse effects of disinfectants, high temperature water, detergent cleaning, and chemicals used in holding and procedure rooms and continuous movement of cages and equipment. If thresholds are used to separate dissimilar flooring materials, provide type that permits the easy wheeling of cages or other equipment through the animal facility. All exposed concrete floors shall be sealed. These are mandatory for animal research facilities. VCT or rubber floor and base materials are not permitted for use in animal research facilities.

### C.3 Carpet:

Use of carpeting when an office is contiguous with the laboratory is not permitted. If carpeting is allowed or used in office areas not contiguous with laboratory, direct glue down installation is required, preferably using carpet tiles. Carpet (modular tile or broadloom carpet) shall comply with all flammability requirements outlined in applicable codes.

## 4-4-10 Design Guidance

### A. Ceilings

## A.1 Lay-in Ceiling Tile:

Lay out ceiling tiles symmetrically so that tiles and grid members retain modular dimensions. All ceiling-mounted items shall be secured through the ceiling to secondary support members. Heavy equipment and equipment tracks shall be securely suspended from independent structural assemblies attached directly to the structural floor and framing members overhead. When acoustic treatment is required in the presence of high levels of moisture, mylar-faced acoustic tiles shall be used. Maximum accessibility in corridor ceilings to the mechanical and electrical distribution systems above shall be provided. Concealed-spline ceiling systems are not permitted. Access panels into ceiling plenums shall be color coded with tabs to identify the type of utility present.

## A.2 Ceiling Treatments:

All areas within the animal facility, except personnel support spaces, require ceilings that are smooth, free of crevices and imperfect junctions with walls, and capable of withstanding scrubbing with detergents, disinfectants, and water under pressure on a frequent basis. Surface mounted lights and exposed pipes are not permitted.

## A.3 Gypsum Wallboard:

Most vivarium ceilings may be constructed of a suspended high density, moisture resistant GWB with an epoxy coating.

## A.4 Access Panels:

Monolithic ceilings, such as suspended GWB or plaster systems, shall be provided with gasketed stainless steel access panels in vivariums. Panel doors shall also be fitted with a gasket. It is recommended that access panels be minimized in animal housing/holding and procedure rooms so as not to disrupt ongoing research and animal care activities. Access panels into ceiling plenums shall be color coded with tabs to identify the type of utility present.

## A.5 FRP Ceilings:

Suspended FRP panels, with heavy duty aluminum suspension system, gasketed with hold down clips are recommended for animal research facilities. FRP ceilings shall not be used in biomedical laboratories.

## B. Walls

## B.1 Wall Treatments:

Selection of wall treatments shall be based on the functional use and purpose of the area, as well as any infection control and chemical resistance requirements. The selection of materials and finishes shall create a non institutional appearance. Sound control and acoustical properties within the area shall be considered when material selection is made. All materials must conform to applicable codes and standards.

- Fabric Finish Materials: No wall coverings are permitted in laboratories for aesthetic reasons, however, may be considered as a protective covering.
- Multicolored Paint Coatings: The use of multicolored paint coatings may be more cost effective than wall coverings; however, this option is a high maintenance item.

# C. Floors

## C.1 Flooring Systems:

Flooring systems that may be considered are:

Linoleum Floor: Use of linoleum floor may be acceptable in biomedical laboratories.

Rubber Floor: Use of rubber floor is acceptable in biomedical laboratories, but not permitted in animal research facilities.

Carpet: The carpet assembly (modular tile or broadloom carpet and padding) must comply with all flammability requirements outlined in applicable codes. The quality of carpet proposed for a facility must be based on several factors, including resistance to wear, soiling and staining. When carpet is used in corridors adjacent to building entrances, walk-off mats shall be provided to extend the life of the carpet installation. Carpet colors should be chosen for their ability to mask soiling to prolong the carpet's appearance. Small irregular patterns and tweeds help mask soiling. Avoid using geometric patterns in high traffic areas such as corridors as these designs may emphasize soiling patterns. Carpet shall also be selected based on the requirements necessary to comply with accessibility guidelines.

Carpet should not be provided in personnel break areas and food preparation areas. While the use of carpet is discouraged in food consumption areas, its aesthetic and acoustical benefits shall be evaluated against sanitation requirements before it is selected for use. If selected for food consumption areas, specify antimicrobial compositions.

VCT: Standard is 3 mm VCT with 100 mm vinyl cove base using continuous versus sectional installation shall be specified with applied adhesive, not self-adhesive. Flooring shall be installed under casework. VCT is not permitted in animal research facilities.

Slip Resistant Surfaces: In addition to code requirements to provide slip resistant ground and floor surfaces, provide slip resistant floor surfaces in all shower stalls. Slip resistant floor surfaces should also be provided in all locations where the floor is subject to moisture or water, e.g., building lobbies.

Resinous/Composite Polyester/Vinyl Flooring Materials: Seamless, monolithic flooring is required within vivarium. Material shall be carried up walls 150 mm minimum, integral with floor with coved corner. A water vapor transmission and core test shall be performed prior to application. Control and expansion joints shall be flush. Surface preparation shall be shot blast. Floor shall slope to drains and top coat shall be slip resistant.

Sheet Vinyl: Seamless vinyl floor and base may be provided in the tissue culture room, heat welded only. Chemical welding is not permitted. Conductive flooring required where static is present, but is generally not permitted in animal research facilities. Some areas within the animal facility may not require the same amount of cleaning and disinfecting as the areas in which cages and animals are held or transported. These areas are program driven and may consider the use of a monolithic sheet vinyl flooring material with heat welded seams. Flooring material shall be carried up the walls a minimum of 150 mm to provide an integral coved base for ease of cleaning.

Vinyl Bases: Continuous versus sectional vinyl base shall be applied with adhesive versus self-adhesive, with a recommendation to use rubber versus vinyl base. When monolithic flooring is used, either a 100 mm high integrally coved sheet flooring base or a readily easily cleaned 100 mm high vinyl or rubber base may be used. Establish mastic performance requirements/standards. Vinyl base is not permitted in animal research facilities.

## C.2 Floor Moisture Protection and Waterproofing:

All “wet” areas shall receive a positive slope to the drain of 6 mm per 300 mm. Floors shall receive a waterproof membrane prior to the installation of the finish materials. The selection of the membrane system shall be coordinated with the flooring manufacturer.

## D. Room Numbering, Signage and Graphics:

ORF DFP determines the room numbering system for the identification of all spaces. This room numbering system shall be incorporated into the design, under DFP guidance, begin-

ning in the design development phases, and reviewed by DFP at the 70% submission, so that all components are coordinated with the building's final room numbers.

## D.1 Interior Signage:

The A/E shall comply with the requirements as defined in the NIH Interior Signage Users Manual. If this manual is not available at the time of the DRM publication, the A/E shall contact the Project Officer for guidance on interior signage requirements.

## E. Window Treatments:

Window treatment is an important element in the overall design solution. Successful window treatment choices must satisfy both functional and aesthetic requirements for the space. Blinds are acceptable choices for interior window treatments. During pre-design programming, the Interior Designer must be involved with the project development to determine the types of window treatments necessary. Elements such as the direction of the source of natural light; the effects of natural light on the user throughout the day, requirements for filtering, blocking, or redirecting light, the effect of natural light in fading of fabrics, the requirements for use of a video monitor, etc. must be considered. Window treatments shall be coordinated with heating and air conditioning to avoid interference with designed airflows.

## E.1 Blinds:

Aluminum blinds may also be used as an interior window treatment. Blind slat depth shall be coordinated with the window frame profile when inside mount units are planned. Neutral colors (black, beige, brushed aluminum, etc.) that will not stand out when viewed fro the exterior of the building are preferred to colors that compliment the interior palette. On new buildings, one color shall be used throughout the building. Windows with integral blinds should be evaluated in addition to the installation of interior mounted blinds.

# Section 4-5: Casework and Equipment



## 4-5-00 Design Requirements

### A. Catalog Cut Sheets & Equipment Groups:

A catalog cut sheet shall be provided for all items of equipment having a logistical grouping of 1 and for any Group 2 and 3 items having unique utility requirements, structural support or space requirements. The following are definitions of equipment by logistical groupings:

Group 1: Contractor Furnished, Contracted Installed
Group 2: Government Furnished, Contractor Installed
Group 3: Government Furnished, Government Installed
Group 4: Movable Equipment and Furnishings

### B. Wood Shelving (Lumber and Facing Materials):

Exposed solid wood shelving and wood faced shelving is not permitted. Use of plastic laminate faced or other core and facing materials may be required for specialized applications.

### C. Biomedical Research Laboratory Equipment:

Refer to HVAC Chapter 6 and Chapter 8 for additional requirements related to specification of equipment that is to be served by building HVAC and plumbing systems.

### C.1 Chemical Fume Hoods:

All containment devices shall be located in the laboratory to avoid entrapment, blocking of egress, or safety hazard to the lab occupant. Fume hoods should be placed distal to the laboratory door and away from laboratory traffic patterns.

### C.2 BSC Placement Requirements for All New Buildings and Renovations: (See Appendix I)

Personnel traffic results in air pattern disruption in BSC's. Therefore, BSC's shall be placed out of the direct traffic pattern of the laboratory and shall not be placed directly across from

one another. Air supply diffusers or exhaust vents shall not be placed directly over or in front of BSC's where the movement of air can affect the airflow of the cabinet.

## C.3 Autoclaves:

For maximum flexibility, an autoclave shall be provided on each floor where microbiological research is performed. Sufficient space shall be provided in the autoclave room to ensure easy access to the serviceable areas of the autoclave. The A/E shall review the requirements of the building personnel when designing and specifying autoclave space. Autoclave space shall be finished with epoxy coatings and shall not have a suspended, acoustical ceiling. This area shall be thoroughly caulked and sealed to promote cleanliness and reduce pest harborage. The space shall have adequate exhaust capacity to remove heat, steam, and odors generated by the use of the autoclave(s). A canopy hood shall be provided over each door of the autoclave. The autoclave space shall operate at negative pressure to the surrounding areas

## D. Layout and Clearances:

Equipment shall be arranged to provide service clearances and maintenance access with minimum disruption to work spaces. When expansion is anticipated in a project, the designer shall allow for the addition of equipment without disruption or reconfiguration of workflow in the layout of sterilizing and sanitizing equipment spaces, or any other spaces affected by the addition.

## E. Floor Preparation:

Floor depressions shall be provided to accommodate cart washers, floor loading sterilizers, radiographic electrical raceways, environmentally controlled room equipment, walk-in refrigerators, audiometric suites, computer rooms, high density shelving, and any other appropriate space except in laboratory spaces where future flexibility is a requirement.

## F. Structural Support:

Wall partitioning systems shall be adequately reinforced for the installation of all wall hung fixtures and equipment such as toilet accessories, physical therapy equipment, radiographic equipment, and hanging supply carts. All fixed equipment shall be mounted to resist seismic forces in accordance with seismic criteria for the region in which the project is being constructed.

## G. Recessed Equipment:

Where sanitation or aseptic requirements dictate, equipment shall be flush, wall recessed or through-wall types to the greatest extent possible.

### H. Special Ventilation Requirements for Equipment:

Control of ventilation for employee working environments must be provided in accordance with the latest edition of the Occupational Safety and Health Act of 1970. Dust and debris collection systems shall be provided for locations where dust and debris is generated. Exterior air supply, exhaust with filtration, and dust containers must be provided.

### I. Equipment Specifications:

The Architect/Engineer shall develop equipment specifications for all equipment that does not have current guide specifications. All equipment specifications should permit procurement of the latest model of equipment from manufacturers through GSA Contracts to the greatest extent possible. Specifications should indicate that the manufacturer has a minimum appropriate level of production experience to preclude the procurement of equipment with untested technologies. Equipment specifications shall fully address the scope of services to be provided by all parties involved in installing Government furnished, Contractor Installed equipment

### J. Lockers in Vivariums

Lockers in vivariums shall have slope tops and solid filled base.

## 4-5-10 Design Guidance

### A. Laboratory Casework:

Laboratory casework shall have smooth non-sharp corners and be easily cleaned, using finishes compatible with materials used for cleaning and disinfection. Metal casework systems shall be provided, unless otherwise required by user's specialized laboratory requirements. Minimum level of quality of casework shall be established by either the NIH Laboratory Casework Specifications, user requirements, or on a per project basis in coordination with the Project Officer. Long runs of fixed casework shall be minimized. Racked equipment, mobile casework on wheels, or other options that minimize cost and maximize flexibility shall be considered. The casework selected shall be interchangeable and readily available so reconfigurations can easily occur.

Fixed casework and countertops shall be sealed to walls and floors during installation to minimize harborage of pests and provide an easily cleaned joint. Refer to Exhibit X4-2-A

"Sealants and Caulking". A/E shall also review caulking and sealing requirements with CHB.

## A.1 Anchorage of Cabinets:

The construction drawings shall indicate how wall cabinets and base cabinets are attached to the partitions. Cabinet installation shall be in accordance with the manufacturer's recommendations. Where cabinets with backs and a hidden 20 mm recess are used, a satisfactory mounting method is to provide solid or slotted 40 mm x 65 mm horizontal steel angles, minimum 1.9 mm metal gauge. The angles are installed with the long legs vertical and with the short leg projecting from the wall to support the cabinet. The bottom angle is installed with the long leg directed up (to be hidden behind the cabinet) and is anchored to every metal wall stud with washers and two #12 metal cutting screws, such as #4 Point #12-24x2 HWH #4 STLG screws having 40 mm of thread length. The top angle, with the long leg directed down, is placed at the level of the top of the wall cabinet, and the vertical leg is anchored to the studs in the same manner as indicated above. The cabinet is slipped between the two angles, and #12 screws at 300 mm on center are screwed downward 300 mm from the back of the cabinet into the hidden cabinet recess to anchor the top of the cabinet to the angle. Similarly, from underneath, #12 screws at 300 mm on center are screwed upward 10 mm from the back of the cabinet into the hidden cabinet recess to anchor the bottom of the cabinet to the angle.

## A.2 Shelving:

Metal shelving shall be provided, unless otherwise required by user's specialized laboratory requirements. Shelving height shall not to exceed 2 300 mm for safe reaching height OR height limitations as determined by DFM, whichever is lower. See Chapter 9 Fire Protection Exhibit X9-2-A "Wall Mounted And Peninsula Shelving Height Policy." This requirement also applies to shelving installed as a component of a laboratory casework system. The typical depth of shelves is 305 mm. Shelving depths shall not exceed 355 mm for wall mounted shelving and 450 mm for peninsula shelving. Depths greater than 305 mm are permitted providing the shelf support spacing is designed for the increased depth.

## A.3 Anchorage of Shelving:

Anchorage of vertical standards carrying shelving brackets shall be capable of safely carrying a fully loaded wall of shelving. A fully loaded wall of shelving consists of a top shelf no higher than 2 300 mm above the floor with shelves spaced 330 mm apart below the top shelf all the way to the floor or countertop. Each shelf shall be capable of supporting a mini mum design load of 7.5 kg per 100 mm of shelf length. A fully loaded wall assumes all

shelves are loaded to capacity. Anchorage for shelving carrying equipment that exceeds the 23 kg per 100 mm of shelf length loading shall be designed for the specific application.

## A.4 Plastic Laminate Faced (PLF) Shelves:

Plastic laminate faced shelves constructed of a particle board or MDF core material shall be a minimum of 30 mm thick and a solid plywood core shall be a minimum 19 mm thick. Shelving shall be faced on all sides and edge banded, including concealed edges. Core material shall be high density fiberboard or other suitable core material for the intended size and purpose. This type of shelving is not permitted in animal research facilities.

## A.5 Shelving Support Spacing:

30 mm plastic laminate faced shelves shall be supported to sides to 32 mm thick (+1.5 mm, -30 mm) by 285 mm wide (+1.5 mm, -30 mm) by 3 000 mm and longer. Four edges shall be eased (rounded) full length, or two edges of one narrow side, full length.

## A.6 Wall Mounted and Peninsula Shelving:

An edge guard shall be provided for the open ends and backs of all shelves not adjoining a wall. In no case shall the spacing between vertical supports exceed 1 200 mm. The cantilevered distance between the last support and the end of the shelf shall be no greater than 305 mm. Staggered depth shelves (top shelf deeper than lower shelves) are permitted.

- Metal Expansion Anchors shall be used in a solid concrete substrate meeting the manufacturer's minimum thickness.
- Adhesive Anchors in a Solid Base Substrate shall be used in a solid concrete substrate and installed in accordance with the manufacturer's printed instructions.
- Screen Tube Adhesive Anchors in a Hollow Base Substrate shall be keyed into hollow base material such as CMU's and installed in accordance with the manufacturer's printed instructions.
- Anchors with Plastic Sleeves Expanded by Sheet Metal Screws are not permitted in animal research facilities.
- Metal Impact Expansion Anchors: These anchors rely on an accurately sized hole, placement of the anchor (composed of a sleeve and a nail), and a hit with a hammer to make the nail expand the sleeve against the sides of the hole.
- Toggle Bolts may be used to attach items to hollow CMU units, assuming a 9 kg maximum load per toggle bolt.

## A.7 Countertops:

Countertop materials will vary depending on usage. Traditional materials such as chemical resistant plastic laminates may be appropriate for some applications. When laminates are used, top and bottom surfaces of the substrate shall be faced and all edges banded. Epoxy resin shall apply to most applications where corrosive chemicals are used or where sinks or heavy water usage occurs. Other new materials shall be investigated for cost effectiveness and durability. All counter tops shall have a drip groove beneath the overhang. Stainless steel shall be used for glassware wash areas, cold rooms, vivariums and other areas as the program requires.

## A.8 Countertop Support Spacing:

Countertop (bench top) support spacing shall not exceed 1,219mm without intermediate supports, and shall be designed to accommodate loading of special bench top equipment identified per program requirements.

## B. Equipment:

A wide variety of laboratory equipment is used in NIH laboratories. The NIH goal is to create adaptability in laboratory space so that instruments can be relocated within the laboratory without altering the space or attendant utility systems and without compromising the operation of the instruments or safety of the users. Some instrumentation rooms, electron microscopy suites, MRI spectroscopy suites, x-ray crystallography suites, and mass spectrometry rooms require special utilities and environmental controls. Comply with the manufacturer's recommendations and see individual technical discipline chapter requirements of the DRM.

## B.1 High Technology Equipment:

The planning for and inclusion of new or unique medical and scientific technology, such as linear accelerators, Positron Emission Tomography and lithotripsy, may require special consultants. The design shall be developed to reflect the equipment selection, as well as recommendations and guidance of the respective manufacturers.

## B.2 Magnetic Resonance Imaging (MRI) Facilities:

The planning, design, and installation of a magnetic resonance imaging (MRI) system in a facility requires extreme care to assure that the magnet is sufficiently isolated from ferromagnetic and radio frequency influences of the impacted environment and that the surrounding environment is isolated from the effects of the magnetic field. Selection of the proper location for the magnet is extremely important and shall be addressed in the earliest stages of the planning and design of the MRI system. The specific guidance of the manu-

facturer of the selected equipment must be followed. Consultants should be used to verify specific requirements.

## B.3 Gas Cylinders:

Commonly used gases such as $CO_2$ shall be supplied from a centralized manifold or bulk storage tank and piped throughout the facility. All applicable warning gauges and valves with protective fusible links or the equivalent shall be included in the design. Note: Some gases (flammable gases) may not be stored outside the laboratory. The A/E shall consult with DOHS regarding placement requirements for specific gases. If cylinders are placed in the lab, they shall be properly secured with cylinder restraints to a vertical surface or counter out of the way of traffic within the laboratory but easily accessible for replacement by hand cart. Appropriate space for such cylinders shall be provided within the laboratory to minimize potential hazards associated with the use of these cylinders and to maximize usable laboratory space.

## B.4 Flammable and Waste Storage:

Flammable-chemical storage cabinets shall be placed in each laboratory and meet applicable fire safety requirements. Space shall be allocated in each laboratory for waste box storage. See Section 1-9 Environmental Management/Radiation Safety.

# C. Animal Research Facility Equipment:

## C.1 Casework and Countertops:

Cantilevered bench tops with mobile casework are preferred. Fixed casework and countertops shall be sealed to walls and floors during installation to minimize harborage of pests and provide an easily cleaned joint. Countertop materials shall vary depending on usage. Stainless steel or epoxy resin shall apply for most applications where corrosive chemicals are used or sinks or heavy water usage occurs. New materials shall be investigated for cost effectiveness and durability. Stainless steel shall be used for glass washing areas and other areas, depending on program requirements. For wall mounted cabinets, tops shall be sloped and sealed.

## C.2 Chemical Fume Hoods and/or Biological Safety Cabinets:

There are certain types of animal research that may require the use of a fume hood and/or BSCs. The determination to include a fume hood and/or BSC within the boundary of the animal facility shall be made with the representative users of the facility, and in consultation with DOHS personnel.

BSCs may be used in some animal holding rooms in lieu of a laminar flow changing station and procedure/treatment rooms. The determination to include a BSC in either location shall be made with the representative users of the facility.

## D. Work Stations:

In addition to following standard design procedures for product and component selection, particular attention shall be paid to providing supplementary space outside the workstations for general, shared use (i.e., conference, library, fax, copier, or other related equipment). All power, telephone, and computer outlets shall be provided well in advance of the furniture installation to give technical installers time to provide necessary services. Installation follow up by the designer is vital to the overall success of the project. Documentation must include, but is not limited to, scaled drawings that indicate panel and component locations, accessories, and a seating and component list of parts. This is necessary for future reconfiguration of workstations.

The interior designer must coordinate design decisions with architects and engineers of the design team to resolve such issues as telephone, electrical, local area networks, and ventilation.

### D.1 Interior Finish Requirements for Prefabricated Furniture Panels:

The flame spread requirements of the NFPA Life Safety Code are to be applied to prefabricated panel furniture systems when such panels are ceiling high or extend sufficiently close to the ceiling so that the larger space divided by the panels is considered to be multiple rooms. The flame spread requirements of the NFPA Life Safety Code are not to be applied to prefabricated panel furniture systems when such panels do not sufficiently extend close to the ceiling so that the larger space divided by the panels is considered to be a single room. The application of flame spread requirements to prefabricated furniture panels does not override any requirements concerning the combustibility of the panels as may be governed by other Standards.

## E. Mail Distribution Equipment:

### E.1 Mail Cluster Boxes:

The ORS Division of Mail and Courier Services (DMCS) requires the use of mail cluster boxes in lieu of door-to-door mail used for delivery of mail to NIH customers in a building. Mail cluster boxes shall be installed at a ratio of one per every 50 building occupants. Mail

cluster boxes shall be centralized in the building lobby but may be decentralized to a single location on each building floor when approved by DMCS.

### E.2 Mail Cluster Box Specifications:

Cluster boxes shall be wall mounted, front loading units with rear covers. Wall mounted cluster boxes shall be thoroughly secured to the building structure. Each unit shall be not less than 288 mm wide x 305 mm high x 407 mm deep. Each cluster box shall be marked with self-adhesive numbers to identify the recipient's mail stop code (MSC), as directed by the DMCS. The construction of cluster boxes shall meet or exceed U.S. Postal Service (USPS) specifications. Each cluster box door shall be secured with a cylinder cam lock, keyed individually and master-keyed (three keys required) for DMCS use. The exterior surface shall not detract from building aesthetics.

### E.3 Mail Drop Boxes:

Two secured mail drop boxes are required at each mail cluster box bank to support outgoing mail services; the first one shall be used for outgoing interoffice mail, and the second for outgoing USPS official domestic and foreign mail.

### E.4 Drop Box Specifications:

Drop boxes shall be wall mounted, front loading units and have a rear cover. The interior of these mail drop boxes shall be sized not less than 458 mm wide x 762 mm high x 458 mm deep. Each drop box shall have a mail slot protected with gravity or spring loaded flap sized not less than 381 mm wide x 102 mm high. These drop boxes shall be secured with cylinder cam locks and be master-keyed (two keys required) for DSS use. Drop box construction shall meet or exceed USPS specifications. At each location, one box shall be marked "Interoffice Mail," and the other marked "Official Mail". The exterior surface shall not detract from building aesthetics.

## 4-5-30 Design Documents Requirements

### A. Equipment Plans and Schedules:

Equipment plans shall be developed as a building system and shall be integrated with the planning of architectural, structural, mechanical, and electrical systems. The A/E shall edit and include any applicable NIH performance specification provided on AIA MASTERSPEC® in the contract documents. See Section 1-10-30-A Lines of Responsibility.

# Section 4-6: Vertical Transportation



## 4-6-00 Design Requirements

The location of elevators shall be such that they are easily accessible and convenient to circulation routes. When additional elevator banks are provided, every effort shall be made to locate them along the same major circulation paths that serve the existing elevators. Ample area for circulation and waiting of staff, visitors, and equipment shall be provided. Elevators shall be located to provide positive separation between passenger and laboratory/service traffic flows.

Elevators shall be located so that they shall serve all floors that require service. This includes the basement, subbasement, and mechanical floors as well as all of the occupied floors of the facility. In facilities that utilize interstitial floors and mechanical penthouses, at least one elevator shall stop on these floors to facilitate equipment maintenance and removal. Elevators shall not be placed over occupied spaces as this shall require counterweight safeties and reinforced pits.

Elevators shall be selected and located to permit transportation of 10 percent of the anticipated visitor and staff load within a 5 minute, two way peak period. The number of elevators required shall be selected on the basis of a 35 second response waiting time interval between elevators.

If one elevator would normally meet the requirements in the facility where elevator service is essential (such as facilities over two stories high), two elevators shall be installed to ensure continuity of service. If financial limitations restrict the inclusion of a second elevator, as a minimum, a hoist way for a future elevator shall be provided.

Special conditions that must receive consideration in estimating elevator usage include visitor traffic, pharmacy, building management, central sterile, surgery, warehousing, grouping of elevators, external transport facilities, building entrances at more than one level, basement facilities, unusual inter floor traffic requirements, trash, lab equipment relocation, deli-

very of gas tanks, and animal rack movement (where elevators are required within or as access to the animal facility).

### A. References:

The A/E design firm shall use and comply with the design and safety guidelines, and references listed in Appendix I.B ,and other safety guidelines received from the NIH Project Officer or as required by the program. The A/E shall utilize the latest editions of reference design and safety guidelines available at the time the design contract award. ASME/ANSI A17.1, A17.2, A17.3, and A17.5 shall take precedence over all other codes. This includes designing to the appropriate rating/load classification for the intended application.

## 4-6-10 Design Guidance

The use of a transportation consultant is recommended to ensure that system selection and design are in compliance with all applicable codes, technical criteria, and analysis of transportation needs, locations, and types. The NIH shall provide program factors that are required for computing traffic demand loads.

### A. Biomedical Research Laboratory Elevators:

Biomedical research laboratory buildings require a combination of passenger/freight elevators. At least one freight elevator shall be located and sized to handle the transportation of materials from the loading dock to the final point of use. This includes access to all floor levels and interstitial levels within each building. The freight elevator requires floor containment to prevent contamination of the elevator shaft in the event of a chemical spill. One heavy duty passenger elevator shall be designed as a freight elevator backup. Both shall be readily accessible to the loading dock.

Material handling zones and marshalling areas on each floor shall be designed adjacent to dedicated service elevators for the purpose of staging, dispensing, and disposing of laboratory and animal facility materials. See Chapter 2 Design Considerations Section 2-3-G “Space Descriptions”, for additional information.

### B. Animal Research Facility Elevators:

Animal research facility buildings require a combination of passenger/freight elevators. In multilevel facilities, dedicated “clean” and “dirty” animal elevators may be required. The elevator for transporting “clean” material shall be located near the “clean” side of the cage wash area, while the elevator used for “dirty” material shall be in close proximity to the “dirty” side of the cage wash area. Program requirements may allow one elevator, the use of

which is coordinated via NIH Standard Operating Procedures. The elevator size and location must accommodate the volume and nature of materials to be handled. Elevators that shall be used for transport of animals and animal facility equipment must be constructed of highly durable and sanitizable materials. The elevator cab wall shall be stainless steel. The cab floor material must be of similar material as the floor in the animal facility. The elevator car interior shall have guardrails at appropriate heights and depth for the typical racks and carts that shall be used in the facility. Elevator doors must be of sufficient height to accommodate the tallest racks that shall be used in the facility. Consideration shall be given to an elevator door width that can accommodate at least two racks side by side.

Unless other alternatives are available, at least one elevator shall have the capacity to handle extremely heavy loads. There shall be adequate redundancy in the number of elevators to handle freight, staff, and animals in the case of an equipment breakdown or regular service. This can be accomplished by providing for flow patterns between "clean and dirty" elevators or other alternatives so that they can serve as backups to each other. The width and height of all hoist way entrances shall be uniform. Guillotine type (vertical bi-parting) hoist way doors shall not be used. Penetration through the shaft shall be sealed in accordance with vivarium caulking and sealing criteria.

## C. Design Conditions

### C.1 Elevator Speed and Type:

Table C.1 indicates parameters for the selection of elevator speed and type. Electric traction elevators are preferred for passenger and service applications. Hydraulic powered elevators may be considered for use where vertical travel is less than 14m or where overhead clearance is limited.

Table C.1: Elevator Speed and Type

| Elevator Rise | | Speed (m/s), by Elevator Type | | |
|---|---|---|---|---|
| *Stops* | *Hgt, m* | *Hydraulic* | *Geared* | *Gearless* |
| 2 | <4.6 | .635 | N/A | N/A |
| 3 | 4.6 to 13.7 | .635 | N/A | N/A |
| 4-7 | <27.4 | N/A | 1.015 to 1.780 | 2.54 |
| 7-17 | 27.4 to 54.9 | N/A | 1.780 | 2.54 to 3.56 |
| >17 | >54.9 | N/A | See Note 1 | See Note 1 |

*Note 1: Consider separate high-rise & low-rise groups of passenger cars.*

## C.2 Elevator Lobbies and Groupings:

Elevators shall be grouped in banks of adjacent cars or banks of cars facing each other. Where four or more cars are required within a group, cars shall be placed in opposite banks, opening to a common lobby. For service and combined use cars, two across are preferred, and not more than three in a row shall be used. For passenger cars, three across are preferred, and not more than four in a row shall be used. Where four or more cars are required within a group, cars shall be placed in opposite banks, opening into a common lobby. Where elevators are accessed from corridors, they shall be located on one side of the corridor only and shall be set back from the line of circulating corridors. Elevator ingress/egress shall be from a distinct elevator lobby and not directly from a corridor. Refer to Table C.2 "Elevator Design Factors" for lobby width requirements. Elevator lobbies generate noise and shall be acoustically isolated from areas sensitive to noise and vibration. Egress stairs shall be located adjacent to elevator lobbies when possible.

Consideration shall be given to the maximum walking distance from the vertical transportation service to the most distant function. This factor shall be weighed along with the advantages of locating elevators near the center of the building and elevator clustering. Refer to Table C.2 "Elevator Design Factors" for walking distances. Any decentralized banks and/or clustering of elevators shall be planned to include at least two cars to maintain an acceptable dispatch interval between cars and to ensure continuity of service.

Table C.2 Elevator Design Factors

| Elevator Design Factor | Passenger | Service/Animal Research Facility |
|---|---|---|
| Lobby Width amid Banks | 3 600mm to 4 200mm | 4 200mm to 4 800mm |
| Max Walking Distance | ≤ 61m | ≤ 61m |
| Optimal Walking Distance | ≤ 46m | ≤ 52m |
| Max Peak Value Interval | ≤ 45 seconds | ≤ 60 seconds |
| Elevator Weight Capacity | 1800 kg | 1,800kg to 2,300kg |
| Elevator Platform Width | 2 400mm | 1 100mm to 2 000mm |
| Elevator Platform Depth | 1 900mm | 2 600mm |
| Elevator Door Width | 1 200mm | 1 200mm to 1 500mm |
| Entranceway Material | Varies | Stainless Steel |
| Elevator Cab Enclosure | Varies | Stainless Steel |

## C.3 Elevator Functional Separation:

Traffic patterns shall be established to separate the various traffic types in an efficient, logical, safe, and secure manner, while maintaining levels of aseptic control consistent with the requirements of the facility. A positive separation of passenger and service elevators shall be provided. Separate "clean" and "dirty" material elevator facilities shall be provided where required.

## C.4 Size and Number of Elevators:

The size and number of elevators required for a given facility depend upon various local conditions such as the size, type, and location of the facility's functional areas, the density of the population, the physical location of the elevator groupings, etc. The elevator installation for a given facility shall be estimated on the basis of anticipated local conditions and quality of service.

The anticipated population density figures shall be provided by the NIH and shall be used for the purpose of designing the required transportation systems. However, in all cases, the vertical transportation requirements shall be planned for the total population that the facility could reasonably house rather than be based on a forecast of initial occupancy.

## C.5 Maximum Traffic Peak:

The A/E shall design to the maximum percentage of the total population on the floors served by the elevators that must be handled during any 5-minute period. This maximum traffic peak will vary with the type of functional areas and special conditions applicable to the facility. The computations for vertical transportation equipment shall be based on transporting 10% to 14% of those persons who move between floors during periods of maximum demand in 5 minutes. The peak values, together with the population density factor, shall provide a reserve capacity adequate to maintain satisfactory service during periods when one elevator is shut down for repairs.

Where groups of elevators serving identical floors are required to be furnished in two or more locations for the purpose of providing convenience of use, the elevators shall provide a minimum carrying capacity of not less than 120% of the maximum traffic peak.

Passenger and service elevators shall have the capability to handle their maximum peak loads while providing a satisfactory interval. Capacity and speed shall be selected that shall require the fewest elevators to handle the peak loads with an acceptable interval. Refer to Table C.2 "Elevator Design Factors" for maximum peak intervals.

## C.6 Limited Rise Elevators:

Oil hydraulic and direct plunger elevator equipment shall be considered for limited rise (four stops, approximately 15 m rise) and low speed elevators. The Elevator Machine Room (EMR) and pump unit shall be located adjacent to the hoist way at the lowest landing. All hydraulic elevators shall have an NIH compatible starter for the pump motor. All hydraulic elevators shall be equipped with a scavenger pump to retrieve the waste oil.

The use of generator field or silicone controlled rectifier (SCR) drive controls is appropriate for unlimited applications.

A single-wrap, geared-traction configuration shall be used for up to 1.8 m/s. A double-wrap or single-wrap, gearless-traction configuration shall be used with speeds of 2.0 m/s and greater. Roping shall be 1:1. Secondary sheaves shall be used with a secondary sheave area. All hydraulic elevators shall be equipped with emergency power outage car return controls.

## C.7 Elevator Operation and Controls:

Special control and emergency service shall be provided in areas serving animal surgery, animal care, and dietary usage. Each elevator bank serving these areas shall be provided with key operated emergency switches for priority service. These switches shall be provided at each landing. This switch will cause the closest available car to bypass other calls in response to an emergency call. An on demand microprocessor system shall be provided for all elevator controls. Three or four car banks shall be controlled in group operation.

Controls shall operate properly with a 500 KHZ to 1,300 MHZ radio frequency signal, transmitted at a power level of not less than 100 watts effective radiated power (ERP) at a distance of 1 m. The equipment shall be provided with electromagnetic interference (EMI) shielding within FCC guidelines. Noise level rating of the elevator equipment and its operation shall not exceed 80 dBa in the EMR's, measured 1 m above the finished floor and 1 m from the equipment.

## C.8 Elevator Capacity and Platform Design:

Platform size is to be evaluated relative to the type of travel and equipment requirements. Refer to Table C.2 "Elevator Design Factors" for capacity and platform sizes.

The maximum size of vehicles or other loads and the maximum weight of portable laboratory, biomedical, or x-ray equipment shall be determined before setting the elevator size and

capacities. The maximum area allowed by the ASME/ANSI A17.1 Standard shall be used to develop the inside dimensions of car enclosures.

## C.9 Elevator Cars:

Car enclosures shall have no front and rear entrance or corner post, shall be of a single entrance type, and shall be of manufacturer's standard design unless modifications are dictated because of special project conditions. Cab design shall be detailed on the project drawings. Refer to Table C.2 "Elevator Design Factors" for materials.

## C.10 Entrances:

Passenger and service elevators shall have single speed, bi-parting horizontal, center opening doors, with infrared screen detectors. Door closing time must comply with ASME requirements. All elevators shall be equipped with buttons to extend door opening time, adjustable between 0 to 30 seconds. The elevator car doors shall be provided with door widths and entranceway materials per Table C.2 "Elevator Design Factors". Tamper proof screws shall be used for all car and corridor fixture plates.

## C.11 Signals:

Hall pushbutton stations shall be provided with call register LED lights and shall be compatible with existing systems and components. Hall lanterns with an audible signal shall be installed on all elevators. Hall position indicators shall be designed visible from each side. Hall position indicators shall be compatible with existing systems and components designed on the control board for compatibility with the existing controllers. Car position indicators shall be installed in each car with floor designations, a floor directory signal, and direction arrows. Car operating panels shall use car register floor rectangular buttons and shall be engraved with building and elevator number. Car operating panels shall compatible with existing systems and components series. A lobby control panel shall be provided on elevator banks with two or more cars. Signal fixtures and gongs shall conform to the requirements of ASME/ANSI A17.1 for use by disabled persons.

## C.12 Seismic Design:

Seismic protection shall be provided as required.

## C.13 Emergency Power Supply:

An emergency power supply shall be provided per ASME/ANSI A17.1 and tailored to the needs of the building. The equipment specified depends on the service demand and the

equipment commercially available to meet that demand. Care shall be exercised to avoid specifying noncompetitive methods in features of elevator dispatching and control operation.

## C.14 Door Operation:

Power door operation shall be provided for all elevators. The door opening shall be capable of opening doors at the rate of 0.9 m/s. This is a capability speed, with actual speed being adjusted to meet the requirements of the specific installation. The closing speed shall be set per ASME/ANSI A17.1. All power operated doors shall be equipped with an automatic reopen device for passenger protection.

## C.15 Elevator Car Enclosure:

Car lighting shall be either indirect or of the luminous ceiling type. Mechanical exhaust shall be provided.

## C.16 Hoist Machine:

Geared and gearless hoisting machines shall be located directly above the hoist way in an EMR where practical by design. For speeds up to 0.5 m/s, alternating current, a two speed control system with a low speed range from 0.15 to 0.2 m/s shall be provided. For car speeds of 0.8 m/s and greater, a generator field control system shall be provided. The hoisting machine and its control system shall be capable of stopping the car at floor level within plus or minus 5 mm of hoist way doorsills. It shall also be capable of correcting for car over travel, under travel, and rope stretch. Car stopping shall be automatic and independent of operating devices. Hoist ways shall be illuminated per ASME/ANSI A17.1.

## C.17 Elevator Machine Rooms:

EMR shall be large enough to install the elevator equipment, including space for controllers, safe clearances, equipment maintenance, and ventilation, and with minimum headroom of 2 300 mm. Sight lines for technicians shall be provided. Control equipment shall be provided with clearances per code to provide access for maintenance. EMR design shall accommodate removal of major equipment components of each elevator for repair without dismantling the components of adjacent elevator(s).

Elevator Machine Room Conditioning: Air conditioning shall be provided in EMRs to maintain ambient temperatures above 15$^{O}$C and below 32$^{O}$C. Provide a minimum of 47 L/s exhaust. Filters shall be provided to remove dust, and are heated and ventilated to accept-

able levels. Reasonable conditions must be maintained in these rooms for worker comfort, to increase equipment life, and to avoid excessive heat gains and losses to adjacent occupied areas.

Heating for equipment spaces generally consists of steam or hot water unit heaters sized to heat the space to 21°C. Heaters shall be strategically located so they can offset infiltration loads caused by leakage through louvers, etc. Isolated pipes within EMR's do freeze and break during severe weather conditions and when other systems fail.

EMRs shall be ventilated, at a minimum, to code requirements for maintaining acceptable Internal Air Quality (IAQ) and internal heat gains that drive ventilation air quantities far above code minimums. The project engineer shall itemize operating equipment and establish estimated heat gains for each space. The ventilation systems shall be sized using a 12°C rise above ambient outdoor air conditions. This results in equipment rooms being as high as 40°C in peak summer months.

EMRs with electronic equipment may require air conditioning instead of ambient ventilation. The project engineer shall define criteria for these spaces and design accordingly. Many times these rooms require air conditioning when building systems are off, thereby justifying the use of packaged spot coolers or fan coil units.

Ventilating elevator shafts and EMRs shall comply per code. It is desirable to filter makeup air for ventilation of all EMR's, but this becomes impractical because of large air quantities in many cases. The ASME/ANSI 17.1 strictly prohibits the installation of any building systems in those rooms unless they serve the space. When locating heating equipment and routing piping within these areas, care shall be taken to minimize the length of run and not to traverse electrical equipment.

Access: EMR access shall conform to ASME/ANSI A17.1. Stairs shall be provided for convenient access to EMRs. Access to EMRs shall preferably not require passage across a roof or similar exposed area.

Electronic, Vibration, and Sound Isolation: All EMRs shall be electronically and acoustically isolated to prevent interference from building electronic equipment and objectionable noises. EMRs shall be acoustically separated from all critical care areas and occupied rooms.

Geared and gearless machines and motor generator sets shall be mounted on vibration isolating and sound isolating devices. These isolating devices, when required, shall conform with seismic design requirements. Trapdoors and hoisting beams shall be installed in all EMR's to facilitate maintenance and removal of equipment for repairs.

Lighting: Adequate lighting shall be provided to ensure proper illumination in the front and rear of all controllers, on supervisory and selector panels, and over each hoisting machine. Convenience outlets shall be provided for each elevator area within the EMR's.

Access Doors: Access doors and frames to secondary levels shall be "B" label and a minimum of 760 mm wide by 1,100 mm high. Each door shall be of the self closing, self locking type and shall have a cylinder lock that requires a key for entry only. Stairway and ladders to access doors shall be installed in compliance with ASME/ANSI A17.1.

## C.18 Elevator Pits:

Elevator pit and drainage shall be provided, including sump pumps, drains, and gratings in locations and sizes per elevator code. Drainage from sump pump shall be connected to the nearest acceptable sanitary line/location.

## D. Elevator Fire Protection

Elevator fire safety arrangements shall meet the latest version of the ASME/ANSI A17.1 Elevator Code and the additional NIH requirements listed.

Provide Phase I Emergency Recall Operation and Phase II Emergency In-Car Operation key switches (which come with the installation of the elevators) for use during construction. After complete installation and before final acceptance by the government, the contractor shall replace the aforementioned switches by installing government furnished Phase I Emergency Recall Operation and Phase II Emergency In-Car Operation key switches. These government furnished switches shall be tested by the government during the final inspection and acceptance testing of the elevators.

## D.1 Phase I Emergency Recall Operation:

A three-position (OFF, ON, and BYPASS) key operated switch for Phase I Emergency Recall Operation shall be provided at only the primary designated level and alternate level for each single elevator or group of elevators. The key shall be removable in the OFF and ON

positions only. The switch shall normally be in the OFF position. Operation of the three positions shall be as follows:

- OFF position – Restores normal elevator service to the elevator or group of elevators served by the switch.
- ON position – Recalls the elevator or group of elevators served by the switch to the designated or alternate level.
- BYPASS position – Restores normal elevator service to all elevators served by the switch, regardless of elevator smoke detector(s) status.

## D.2 Smoke Detectors:

Smoke detectors (multiple detectors where lobby areas are large enough to require them) shall be provided in each elevator lobby/landing and in all EMRs. Smoke detectors shall not be installed at the top of the elevator shaft/hoist way.

The activation of a smoke detector in any elevator lobby/landing, other than the designated level, or in any associated EMRs shall cause all cars in the group (common to the EMR or hoist way) to return nonstop to the designated level in conformance with the requirements of ANSI A17.1.

If the smoke detector at the designated level is activated, the operation shall conform to ANSI A17.1 except that the cars shall return nonstop to an alternate level approved by DFM. The first elevator recall detector shall lock in the recall function and not be overridden by a subsequent detector activation.

## D.3 Phase II Emergency In-Car Operation:

A three-position (OFF, ON, and HOLD) key operated switch for Phase II Emergency Recall Operation shall be provided in all elevator cabs. The key shall be removable in the OFF, ON, and HOLD positions. The switch shall normally be in the OFF position. Operation of the three positions shall be as follows:

- OFF position –Automatically causes the elevator to return to the “designated level” for use by later arriving firefighters.
- ON position – Permits the firefighter to take control of the elevator, overriding automatic operations.
- HOLD position – Allows the firefighters to remove the key and leave the car without danger of the car being taken to another floor.

## D.4 Sprinklers in Elevator Machine Room:

Sprinklers shall be provided in all EMRs. Sprinklers shall be rated between 80°C and 107°C and be equipped with sprinkler guards. The temperature rating of the sprinklers in the EMR must be higher than that of the heat detectors (57.2°C). Sprinklers shall not be provided in elevator hoist ways.

Fixed temperature (57.2°C) heat detectors shall be provided in each EMR. Activation of a heat detector shall cause shunt trip breaker(s) to disconnect the main line power to the affected elevator. The actuation of heat detector(s) shall cause a "supervisory alarm" on the building's fire protective signaling system, if provided. No heat detectors are required in the elevator hoist way. Heat detectors shall be placed within 0.61 m laterally of each sprinkler.

A sprinkler system water flow switch shall be provided for the EMR sprinklers. It shall not be equipped with a time delay mechanism, and the water flow switch shall not cause elevator power to shunt trip. Each sprinkler supply line serving EMR sprinklers shall be equipped with an electrically supervised (tamper switch) control valve located immediately outside the EMR.

For buildings with a multiplex/addressable fire alarm system, the interruption of power to the elevator driving machine upon activation of heat detectors in the EMR's shall be accomplished through the fire alarm system software. The elevator shall perform Phase I recall prior to the interruption of power.

## E. Isolation of Material Handling and Transportation Systems:

Pneumatic tubes and vertical conveyors shall not be located adjacent to any acoustically sensitive space and shall be resiliently isolated from the building structure at each floor penetration by means of rubber-in-shear or glass fiber isolators providing a minimum static deflection of 10 mm. The exterior of each large pneumatic tube shall be coated with a viscoelastic, vibration damping compound or other damping material.

Wherever possible, other vertical and horizontal system runs, such as pneumatic tubes, conveyors, and monorails, shall not be located adjacent to, over, or under any acoustically sensitive space. They shall be isolated from the building structure by resilient hangers, isolated support traps, resilient pads, or trapeze hangers and shall have no direct physical connection with the finished ceiling system of the space below. If the horizontal runs are routed over acoustically sensitive spaces such as private offices or examination and treatment rooms, the pneumatic tubes shall be coated with viscoelastic damping compound or other damping material, such as a 25 mm thick glass fiber blanket, with an impervious outer

covering such as metal foil. Other pipe sleeving material is available. These materials can be shop applied for the majority of the system run, with field application required only at the joints. If horizontal tube runs are routed over acoustically critical spaces, such as animal breeding or NMR imaging, a suspended ceiling system providing a sound isolation rating in the range of NIC 40 shall be required in addition to the resilient isolation of the service runs. Alternatively, these system runs can be boxed, encased, or wrapped with an impervious barrier material such as dense plaster, gypsum board, or a 50 mm thick glass fiber material (96 kg/m3 density) or covered with an impervious outer wrapping such as reinforced leaded vinyl or sheet lead.

In addition to resiliently isolating the service from the building structure, the drive units, transfer or diverter units, and exhauster associated with each type of system runs, motors, pumps, compressors, and gear and drive assemblies shall also be isolated.

## F. Elevator Controls

### F.1 Controller:

All new elevator installations and upgrades to existing elevators shall be equipped with a solid-state microprocessor based controller compatible with existing NIH campus-wide controller systems. Hydraulic controllers are recommended for hydraulic elevator applications. For all locations, coordinate with campus-wide controller system.

### F.2 DC-SCR Drives:

All new elevator installations and upgrades to existing elevators shall be equipped with a DC silicone controlled rectifier (SCR) drive in lieu of motor generator sets. Provide the latest version SCR drive for elevator hoist motors that is compatible with the existing NIH campus elevator components and systems.

### F.3 Fixtures:

All new elevator fixtures shall be engraved with building number and elevator number and include light-emitting-diode (LED) illumination; and the hall stations shall be engraved with the fire station information. All fixtures shall be compatible with the existing NIH campus elevator components and systems.

Car operating panels shall be compatible with the existing NIH campus elevator components and systems, equipped with emergency lighting, digital position indicator, and built-in auto-dialer telephone with call-tracking capability and fire fighter return service controls and

signals. An integral floor announcer shall be provided to announce floor stops; car direction, nudging, and firefighter's return service. Floor buttons shall be rectangular in shape with numerals and LED illumination. Car station shall be provided with a 120 V GFC1 receptacle and include the following key switch arrangements:

- Inspection key switch duo.
- Car lighting key switch duo.
- Fan key switch duo.
- Independent service key switch duo.
- Hall access key switch duo.

## F.4 Door Operators:

All new elevators shall be equipped with door operators for standard and bi-parting freight doors; and all freight elevators shall be equipped with door operators for horizontal doors, compatible with the existing NIH campus elevator components and systems.

# Section 4-7: BSL3 & ABSL3 Biocontainment



## 4-7-00 Design Requirements

### A. BSL3 General Architectural Containment Components:

### A.1 Containment Barrier:

The BSL3/ABSL3 secondary containment barrier is comprised of the physical walls, ceiling and floor of the laboratory and is essential for maximum protection of the environment outside the laboratory.

### A.2 Containment Barrier Substrate:

The BSL3/ABSL containment barrier substrate shall be designed using known construction systems. System options shall be dimensionally stable and free of excessive differential movement from thermal expansion, contraction, shrinkage and structural deflections and settlement. Options include metal studs and wall panels, concrete masonry units, cast-in-place concrete or modular panel systems that are bonded, or mechanically fastened together.

All substrate systems shall be capable of bonding to a high performance coating system or shall be a composite substrate and finish system. All substrate systems after installation shall meet the requirements of NIH Supplement on Laboratory Test Criteria and the “chemical resistance and finish criteria” of this chapter.

### A.3 Containment Barrier Substrate Performance:

The stable containment barrier substrate shall be suitable for special coatings applications and shall be monolithic in nature designed uniformly using same materials.

Directional air flow shall be the primary containment concept for BSL3 biocontainment laboratories built to maintain negative air pressure differentials. The containment barrier shall meet “NIH Biosafety Level 3 – Laboratory Certification Requirements” and shall be structu-

rally stable when the room is subjected to the maximum negative pressure achieved in failure scenario testing. See Chapter 6 and Chapter 7 HVAC and Building Automation Systems.

The biological barrier formed by the finish coat or finish system applied to the substrate, a structural back-up wall, shall be integral to that substrate wall. This composite system of substrate and finish shall withstand the range of pressures associated with the negative air pressures of the HVAC system. The barrier system shall be resistant to decontamination chemicals.

All services and components that penetrate the containment barrier shall be integral to the substrate for both structural integrity and pressure resistance. All penetrations shall be integral with the finish system or high performance coating system that will conform to NIH supplement on laboratory criteria.

## B. BSL3 Laboratory Finishes:

Design features and materials selected for the construction of laboratories shall be durable, smooth, easily cleaned, provide ease of maintenance, minimize pest access, and contribute to the creation of a comfortable, productive and safe work environment. The main criteria for high performance coatings or manufacturer applied composite systems within containment facilities are chemical resistance, smoothness, durability, and ease of cleaning. Finish material, factory or field installed, shall be selected based upon these and other project specific set of criteria. Consideration shall be given to the corrosive chemical activity of disinfectants, decontamination gases/vapors, and other chemicals used in the laboratory. Selection of materials and design of penetrations through walls and floors have an impact on fire safety in buildings. See Chapter 9. Fire Protection.

Finishes and construction details shall provide a barrier against the harborage of pests and vermin. Joints between dissimilar materials shall be considered as a stress point and shall be constructed to prevent cracking. All penetrations shall be sealed and should be visible for routine inspection and maintenance. Selection of materials and penetrations through walls and floors shall be coordinated with DOHS. See Section 1-11 Integrated Pest Management. General penetration requirements for engineering systems are also discussed in Chapter 6 HVAC, Chapter 8 Plumbing, Chapter 9 Fire Protection, and Chapter 10 electrical.

Flooring shall be seamless, nonabsorbent, and slip resistant. The flooring shall be resistant to the adverse effects of laboratory chemicals, detergents, cleaning materials and deconta-

mination chemicals. Base shall be integral to the flooring and be a minimum of 100 mm high.

Walls and ceilings shall be finished with a scrubbable, chemically resistant material, free from cracks, unsealed penetrations and imperfect junctions at ceilings and base. Materials shall be capable of withstanding the effects of strong detergents and disinfectants and be capable of withstanding the impact of normal traffic. In glassware washing and autoclave rooms, the ceilings shall be constructed of moisture resistant substrate with a moisture resistant finish such as epoxy paint.

Table B.1: Recommended Minimum Substrate & Finish Requirements

| Substrate | BSL3 | ABSL3 | Cabinet Lab | Support |
|---|---|---|---|---|
| GWB | EP | SPC | SPC | EP |
| CMU | EP | SPC | SPC | EP |
| CONC | EP | SPC | SPC | EP |
| FRP | Factory | Factory | Factory | Factory |

*Legend:*
*CONC - Concrete*
*CMU – Concrete Masonry Unit*
*EP – Epoxy Paint*
*FRP – Fiberglass Reinforced Panel*
*GWB - Gypsum Wallboard*
*SPC – Special Coatings*

## C. Caulking and Sealants:

The A/E shall coordinate requirements with and receive guidance from the Project Officer and DOHS on caulking, sealing and pest management related issues prior to the commencement of a project.

Caulking and sealants in a BSL3 environment are used for both finish work and for pest management. In addition to Exhibit X4-2-A Joint Sealants and Caulking for Pest Management, the following Exhibit X4-7-A “Caulk and Sealant Matrix for BSL3” for sealants in containment areas shall be incorporated into containment zones.

## D. Doors

## D.1 BSL3 Doors and Frames:

BSL3 laboratory doors and frames shall be fully welded; knock-down frames are not permitted. Frames must be sealed to eliminate air infiltration. The finishes shall be scrubbable and chemically resistant. Vermin control shall be provided. Refer to Section 1-9 Integrated Pest Management. Doors shall be sized for the ingress/egress of laboratory equipment and shall have door protection including, but not limited to lever guards, mop plates and kick plates. Laminated and/or tempered glass shall be used and shall be fully glazed to resist air infiltration. Coordinate door and door frames with the DPSM and DOHS requirements for physical security.

Access panels should be minimized as much as possible, but when unavoidable follow the requirements set forth. Access panels into ceilings and walls shall be gasketed and secured by latches that ensure a gas tight seal for gas decontamination. Access panel frames shall be sealed to the containment barrier. Ceilings open to the structure above (open ceilings) may be acceptable provided minimal ducting and piping is present and all exposed surfaces are smooth and easily cleaned. Access doors should be avoided as much as possible in BSL3 containment and where used, the use, design and sealing shall be subject to DOHS approval.

## D.2 BSL3 Door Hardware:

Interlocking doors shall be included at all primary entrances into BSL3. Vermin control and pest management shall include mortise latch seals and caulking. Refer to Section 4-7-00-C. Caulking and Sealants. BSL3 security and access control is program driven; consultation with the DPSM and DOHS shall be required for hardware and security devices that interface with the BAS system.

## E. BSL3 Laboratory Windows and Frames:

All window frames shall be fully welded. Knock down frames are not permitted. The finishes shall be scrubbable and chemically resistant. Vermin control shall be provided. Refer to Section 1-9 Integrated Pest Management. Laminated and tempered or tempered glass lites shall be used and shall be fully glazed to conform to “NIH Biosafety Level 3 – Laboratory Certification Requirements.”

## F. Casework and Furnishings:

## F.1 BSL3 Laboratory Casework:

All casework shall be metal and constructed to eliminate warping or ‘oil-canning’ of surfaces. Finishes shall be compatible with chemicals used for decontamination and cleaning.

Adjustable standards and devices shall be cleanable. Standards that contain multiple slots and concealed spaces are not permitted. Mobile cabinets shall be considered to maximize flexibility and allow for ease of cleaning. All work surfaces shall be easily cleaned utilizing seamless, solid and chemically resistant finishes such as epoxy resin. Consideration shall be given the height adjustable work surfaces within the BSL3 laboratories and shelving height shall be located in accordance with the requirements of NFPA 13 and DFM. Any joints, holes and connections at walls and flooring shall be sealed to avoid the harborage of pests and debris and allow for ease of decontamination and cleaning. Caulking and sealing requirements shall be reviewed with the DOHS. Refer to the caulking and sealant matrix for specific guidelines. Where glazing is required in upper casework, the quantity shall be limited and shall be safety glass. For laboratory benching within cage wash areas and any other wet area where program requirements dictate, stainless steel casework shall be utilized. Refer to Chapter 8 Plumbing for requirements for hands-free faucets.

### F.2 BSL3 Laboratory Seating:

BSL3 laboratory seating shall consist of armless, adjustable height stools with base of adequate stability. The seat material shall be capable of being sanitized, stain resistant, and impervious to liquids, oils and mildew.

### F.3 BSL3 Signage:

In areas where infectious material are present in a containment laboratory a hazard sign incorporating the universal symbol for biohazard shall be posted on all doors providing access to the space.

## 4-7-10 Design Guidance

### A. BSL3 Equipment:

In addition to the requirements listed in other sections of the DRM, due care and diligence shall be taken to identify equipment placed inside the containment zones. Government supplied equipment shall be reviewed for decontamination compatibility. Equipment services that interface with or penetrate the containment barrier shall be detailed to conform to “NIH Biosafety Level 3 – Laboratory Certification Requirements.”.. Vibration analysis shall be performed to mitigate any influences above and beyond any manufacturer’s equipment tolerances. See Structural 5-2-00-C “Vibration”.

### A.1 Biological Safety Cabinets:

Biological safety cabinets (BSCs) are typically limited to Class I and Class II type. The A/E shall assist in equipment selection and make recommendations based upon program requirements. Equipment selection shall be reviewed with the end user and DOHS for conformance to scientific and programmatic goals during the planning stage.

Refer to criteria discussed in Section 4-5-00-C.2 for placement of Biological Safety Cabinets (BSCs). Recognized standards for BSCs include: America National Standard for Laboratory Ventilation; ANSI/AIHA Z9.5-2003 approved September 30, 2002 and NSF International Standard/American National Standard for Class II (laminar flow) BSC, NSF/ANSI 49-2004 adopted February 24, 2004. The standards include basic requirements for the design, construction, and performance of BSCs that are intended to provide personnel, product and environmental protection, reliable operation, durability and structural stability, ease of cleaning, limitations on noise level, illumination, vibration, and motor/blower performance.

BSCs shall be located out of the mainstream of traffic or at the end of an isle to minimize the air currents at the cabinet face. A work zone shall be identified in front of the BSC equal to the width of the cabinet and extending (915mm) in front of the cabinet. This clear floor space shall not overlap with another BSC. Staggered BSC arrangements are preferred.

The A/E shall be responsible for coordination of exhaust system connections to BSCs. See Chapter VIII.HVAC and refer to the ACGIH, Industrial Ventilation, a manual of recommended practices.

BSL3 Aerobiology: Aerosol challenges shall be conducted within a Class III cabinet capable of withstanding rigorous decontamination using chemicals required by the program. The BSL3 laboratory in which a Class III BSC is located shall meet the BLS3 laboratory requirements. All services shall be sealed. Class III BSCs shall have a separate and independent exhaust system.

All materials in a Class III BSC shall be decontaminated prior to exiting the cabinet. Drains are not allowed. An in-line double door sterilizer sealed to the BSC and a dunk tank or fumigation chamber shall be integral to the BSC.

The Class III cabinet supply air shall be single HEPA filtrated. Exhaust air from a Class III shall be a dedicated system with double HEPA filters in series.

## A.2 Autoclaves:

Size and configuration of sterilizers shall be based on program needs. All sterilization cycles and options are program driven. Autoclave chamber size and door configuration are to be determined by the program requirements as well as the protocols for decontamination of the BSL3 laboratory. Single door autoclave may be used in a BSL3 lab; however, double door autoclaves in new facilities are preferable.

Autoclaves integral to the containment barrier of a BSL3 laboratory require a manufacturer supplied bioseal. The bioseal shall be in the containment wall. The biological seal between the autoclave and the containment barrier shall be a structurally stable, mechanically fastened gasketed seal capable of containing decontaminating gas. Allow for differential movement of autoclave during the hot and cold cycles. Barrier shall remain intact for gaseous decontamination protocols, and shall conform to the "NIH Biosafety Level 3 – Laboratory Certification Requirements.".

Services required by the autoclaves shall be sealed. Double door or pass through autoclaves require interlocks on doors to prevent non-containment or "clean" side contamination. Interlocks shall be connected to the Building Automation System as per Chapter 7.Building Automation Systems for monitoring and alarm. A sink shall be provided on the non-containment or "clean" side of bulk autoclaves for receipt of decontaminated liquid waste. Autoclaves shall not open directly onto a corridor, but shall open into a non-containment autoclave vestibule. The vestibule shall have a door(s) separating the autoclave from the corridor.

Exhaust hoods shall be located on both the non-containment or "clean" side and containment or "dirty" side of large bulk double-door autoclaves, medium single door autoclaves and small autoclaves. Exhaust hood on the containment side are connected to the BSL3 or ABSL3 exhaust system and are HEPA filtered. Refer to Section 6-4 HVAC and Appendix E.5 for exhaust hood requirements. Autoclaves shall be designed to preclude escape of chamber contents prior to sterilization. Pressure relief lines shall be discharged to a safe area in accordance with the risk assessment and the floor sink for receiving the sterilized chamber condensate shall be located on the clean side of the bioseal, typically in the utility service access space. Refer to Chapter 8 Plumbing.

## A.3 Cell and Tissue Imaging Equipment:

The inclusion of Cell and Tissue Imaging Equipment , but not limited to Electron Microscopes, Cryo EMs and plunge freezers in a BSL3 environment shall require additional design precautions to those provided in Section 4-5 and Chapter 2. Serviceability and decontamination of equipment shall be considered from maintenance and biosafety standpoints.

Proximity of imaging equipment to adjacent equipment or areas of ferrous activity (loading docks, cart movement, elevators, etc.) shall be reviewed for shielding requirements and coordinated with the containment barrier.

Local codes and authorities shall be consulted if any quantities of flammable materials are required for the plunge freezing of samples. Fire safety features shall be coordinated with the biosafety features of a BSL3 environment

### A.4 LN2 Freezers:

Security protocols and access control to freezers shall be determined by the user's program. LN2 piping and penetrations shall be coordinated with containment construction requirements of a BSL3 environment. If tanks are to be used, consideration shall be given to decontamination and disposal provisions.

### A.5 Dunk Tanks:

Dunk tanks are not typically used in BSL3 applications. Dunk tanks are one method of passing samples from BSL3 to a lower level of containment. If utilized, dunk tanks shall be integral to the containment barrier. Size and location of dunk tanks shall be determined by program. Dunk tanks shall be lockable and open into an enclosed, secure space such as the anteroom, fumigation, or sterilizer vestibule. Construction of dunk tanks shall be fully welded stainless steel with smooth, cleanable edges. The inside of the tank may be required to have a chemical resistant high performance coating. A view panel shall be installed above the dunk tank for visual communication.

Testing of the dunk tank assembly will be required. The depth of the partition must exceed the expected maximum pressure differential. Dunk tanks are integral to the containment barrier and will be required to meet the performance criteria of "NIH Biosafety Level 3 – Laboratory Certification Requirements." This test complies with the ARS 242.1 guidelines.

## 4-7-20 Design Information

The A/E shall refer to Sections 2-5 and 2-6 in Chapter 2 and the preceding sections of this chapter and make a determination of all applicable provisions that are to be incorporated into the design of the biocontainment facility.

## 4-7-30 Design Document Requirements

## A. Architectural Plans (Design Development and Contract Documents)

Floor plans, sections, elevations, reflected ceiling plans, wall sections, roof plan, parapet or edge details, roof penetration details, interior elevations, finish schedules, door elevations, door schedule, door (jamb, head and thrush) details, window elevations, window schedule, window (jamb, head, and sill) details, equipment and casework layout, equipment and casework schedules, miscellaneous details, and cover sheet requirements.

## B. Specifications (Outline and Detail Performance Specifications)

Outline specifications shall be developed at the design development stage and detail performance specifications shall be developed at the contract document stage.

## C. Cost Estimates (Systems and Quantity Takeoff Estimates)

Systems cost estimates shall be developed at design development stage and quantity takeoff estimates shall be developed at the contract document stage.

# Caulk and Sealant Matrix for BSL3

| Group | Description | BSL3 areas | | |
|---|---|---|---|---|
| | | BSL3 | ABSL3 | Comments |
| Doors: | Seal all penetrations in doors | JS-1 | JS-1 | |
| | Seal door, frame and wall interface | JS-8 | JS-1 | |
| | Seal lock sets and door frames | JS-1 | JS-1 | |
| | Seal door thresholds to floor | JS-6 | JS-6 | |
| | Caulk around louver | JS-1 | JS-1 | |
| | | | | |
| Cabinetry/Shelving: | Seal openings in shelf bases and table legs where support feet mount | JS-1 | JS-1 | |
| | Seal all cabinets where in contact with dissimilar materials | JS-1 | JS-1 | |
| | Seal all cabinets where in contact with one another | JS-1 | JS-1 | |
| | Seal all counter tops at joints and connections | JS-3 | JS-3 | |
| | Seal around all shelf support brackets to shelves and walls | JS-1 | JS-1 | |
| | Seal unistrut rails | JS-1 | JS-1 | |
| | Seal peninsula unistrut shelving support at countertop and at ceiling | JS-1 | JS-1 | |
| | Seal tops and bottoms of wall mounted shelving brackets | JS-1 | JS-1 | |
| | Seal all gaps and openings in stainless steel racks | JS-1 | JS-1 | |
| | | | | |
| Walls/Floors/Ceilings: | Seal all interior window frames (including gasketed areas) | JS-8 | JS-8 | |
| | Seal all surface-mounted plates at floor | JS-6 | JS-6 | |
| | Seal all surface-mounted plates at gypsum wallboard ceilings | JS-1 | JS-1 | |
| | Sound sealant | JS-8 | JS-8 | |
| | Seal all wall surface-mounted cover plates | JS-1 | JS-1 | |
| | Seal all ceiling surface-mounted cover plates | JS-1 | JS-1 | |
| | Seal and cap the tops of all CMU walls | JS-7 | JS-7 | |
| | Seal around all metal cap strips at top edge of epoxy cove base | JS-2 | JS-2 | |
| | Seal control joints in gypsum board walls and ceilings | JS-2 | N/A | |
| | Seal control joints in floors | JS-6 | N/A | |
| | Seal joints between walls of dissimilar materials | JS-2 | JS-2 | |

| Group | Description | BSL3 areas | | |
|---|---|---|---|---|
| | | BSL3 | ABSL3 | Comments |
| | Seal space in wall penetrations including inside sleeves, collars and surrounding construction | JS-1 | JS-1 | |
| | Seal all duct work that penetrates wall envelope | JS-1 | JS-1 | |
| HVAC: | Hot water line insulation shall be wrapped in aluminum and the seams and ends of the insulation caulked and sealed | JS-1 | JS-1 | |
| Plumbing: | Seal at vacuum pass-through | JS-1 | JS-1 | |
| | Seal all cracks in foam rubber water line insulation | JS-1 | JS-1 | |
| | Seal all flat escutcheon plates/support standoff brackets for animal water systems | JS-1 | JS-1 | |
| | Seal all gaps of 6.4 to 9.5 mm or less | JS-1 | JS-1 | |
| | Seal all piping that penetrates wall envelope | JS-1 | JS-1 | |
| Electrical: | Seal perimeter of all electrical panels | JS-8 | JS-1 | |
| | Seal joints between ceiling and light fixtures in hard ceilings | JS-8 | JS-1 | |
| Equipment: | Seal all sinks when in contact with other surfaces including mounting and support brackets | JS-1 | JS-1 | |
| | Seal all large gaps with foam backer rod and caulk in place | JS-1 | JS-1 | |
| | Seal gaps between stainless steel sheet metal at cage/rack washers and tunnel washers | JS-1 | JS-1 | |
| | Seal around frames, holes, hollow channels inside of fire extinguisher boxes. Seal frame and glass where no clips present. | JS-8 | JS-1 | |
| | Seal around any metal rod hangers where ceiling is penetrated | JS-1 | JS-1 | |
| | Seal wall mounted heating/air conditioner unit casework and utility penetrations | JS-8 | JS-1 | |
| Fixtures: | Toilet | JS-4 | JS-4 | |
| | Sink Faucet | JS-4 | JS-4 | |
| | Wall hung equipment | JS-1 | JS-1 | |

*Sealant Types:*
*JS-1 - Silicone - ASTM C920 Type S, Grade NS, Class 25*
*JS-2 - Silicone - Paintable - ASTM C920 Type S, Grade NS, Class 25*
*JS-3 - Silicone - ASTM C920 Type S, Grade NS, Class 25 and 21 CFR 177.2600 (contact with food)*
*JS-4 - Silicone - Mildew resistant - ASTM C920 Type S, Grade NS, Class 25*
*JS-5 - Silicone - Structural - ASTM C920 Type S, Grade NS, Class 50*
*JS-6 - Urethane - ASTM C920 Type S, Grade NS, Class 25.*
*JS-7 - Urethane - ASTM C920 Type M, Grade NS, Class 50.*
*JS-8 - Acrylic - ASTM C834 Type P, Grade NF.*

The above list contains the majority of areas to be caulked/sealed to reduce pest harborage, but is by no means finite, and shall be a supplement to other joint sealing specifications. Coordination with fire protection seals and fire caulking shall be discussed with the DFM and DOHS.

# Structural

5



# Section 5-1: Structural Design Considerations



## 5-1-00 Design Requirements

### A. Planning Module:

The laboratory planning module shall be considered the primary building module in multi-use facilities due to the importance of the laboratory-planning module to functional and safety issues.

Early planning and coordination of the entire design team is critical. Close coordination between structural and mechanical disciplines is critical to minimize interference of piping and ventilating systems with structural framing. Columns shall not fall within the laboratory-planning module to prevent interference with facility space planning and laboratory layouts, and inefficient use of valuable space.

### B. Future Expansion:

Specific plans for future vertical or horizontal expansion shall be considered during the programming and planning stages, and accommodated during the design stage. Provision shall be made for the addition of future floors and additions as determined by the NIH on a project-by-project basis. Future expansion plans, including assumed type of construction and live loads shall be shown on the drawings.

### C. Equipment Pathway:

The potential routing or pathway for the addition or relocation of heavy equipment shall be identified during the planning phase, so that floor loading can be accommodated during the design phase. The pathway of heavy equipment shall be designated on the construction documents and designed to accommodate floor loading. Where there are occupied areas below grade extending beyond the exterior building walls above grade, the roof area of the below grade spaces shall be designed to support fire fighting equipment.

## D. Structural Bay Size:

Both vertical and horizontal dimensions of the structural bay shall be carefully evaluated with respect to the laboratory planning module, mechanical distribution, and future expansion plans.

The horizontal dimension of the structural bay shall be a multiple of the laboratory-planning module dimension to provide for maximum flexibility and regular fenestration; and to allow uniform points of connection for laboratory services with respect to the laboratory-planning module.

## E. Geotechnical Report:

The geotechnical report prepared by a register geotechnical engineer, shall include test borings in soil, and rock coring, if rock is encountered and provide information as to the types of soil encountered, allowable bearing pressures, differential and absolute settlements, lateral soil pressures, suggested types of foundations, water table, drainage requirements, preliminary recommendations for sheeting and shoring, and special foundation problems. The geotechnical report shall be included in the construction documents. The geotechnical engineer shall be retained to prepare a comprehensive geotechnical investigation (report) prior to structural foundation design, verify materials encountered during construction, and monitor earthwork operations.

## F. Level of Concrete Finished Floors:

Unless otherwise specified, a concrete floor shall be level, ±3 mm in height in 3 050 mm in any direction, measured at any point of the floor. Floor flatness (FF) and floor levelness (FL) numbers shall be specified when the installations of finish materials, functional conditions, or equipment dictates tight control to assure top slab surface is constructed, essentially, “dead-level.

## G. Post-tensioned Concrete:

Inadvertent cutting of post-tensioned concrete is a safety hazard, and if cut, steel strands may eject from the ends of the tubes into which they were placed or otherwise create danger to personnel. No holes shall be cored or other demolition shall occur prior to locating tension strands by conducting ground-penetrating radar and/or pacometer testing, and recorded under the supervision of a registered structural engineer. Information is to be provided to the A/E for designing a procedure under which the demolition work is to be done and demolition is required to be performed under A/E’s supervision.

# 5-1-10 Design Guidance

## A. Structural System:

The structural system for NIH facilities includes subsystems' specific performance requirements as follows:

### A.1 Foundations:

The foundation system shall be of sufficient size, rigidity, and strength to resist all imposed loads without deflection or settlement that would result in damage to any building systems or affect the facility's operations.

### A.2 Grade Level Framing:

Slab and grade beam bottoms, may be supported by site soils if subsurface conditions are acceptable -- based on a geotechnical investigation.

### A.3 Foundation Walls:

Basement and foundation walls shall consist of cast-in-place concrete with control joints at 6.1m maximum spacing, with construction joints at 12.2m maximum spacing to minimize cracking.

### A.4 Columns, Beams, Girders, Concrete Pan Joist, Steel Joist, Concrete Slabs and Steel Decking:

Typical, acceptable structural framing may consist of concrete framing, steel framing, concrete for lower levels and steel framing at higher levels depending on the research to be conducted. Buildings that will house vibration-sensitive research require evaluation of the framing system prior to selection, by a vibration consultant acceptable to the NIH, for compatibility with the research equipment vibration limitation tolerances.

### A.5 Lateral Load Resisting System:

The lateral load resisting system shall be selected to provide the stiffness required with a minimal impact on facility operations while providing for the highest redundancy. Moment resisting frames, braced frames, or shear walls are preferred.

### A.6 Secondary Structural Support:

Secondary structural support for equipment shall consist mainly of structural steel framing hung from the structure above, supported by posts from the floor below, or bracketed off adjacent walls, as reviewed and approved by the vibration consultant. The design of secon-

dary structural supports shall consider the movement, vibration, maintenance, and seismic forces related to each element supported.

### A.7 Bracing of Non-Structural Items:

Architectural, mechanical, and electrical components shall be designed and anchored to resist seismic forces in accordance with latest edition of the IBC.

## B. Animal Research Facilities Structural Planning:

### B.1 Structural Bay Size:

Both vertical and horizontal dimensions of the structural bay shall be carefully evaluated with respect to the functional requirements of animal facility spaces, the primary building module, mechanical distribution, and future expansion plans.

The horizontal dimension of the structural bay shall be a multiple of the planning module or primary building module dimension for maximum flexibility, and to allow uniform points of connection for animal research facility services.

### B.2 Location:

The A/E shall attempt to locate animal research facilities on grade-supported slabs, so as to reduce vibration concerns, easily accommodate pits required for cage and rack processing, and eliminate the risk of water leakage to lower levels.

### B.3 Vibration:

Animal research outcomes can be affected by vibration. Refer to Paragraph II.B.3.c “Vibration” of this chapter to control vibration and to locate vibration sources away from animals.

### B.4 Floor Slab Depressions:

Floor depressions and/or topping slabs shall be evaluated for use in special-finish areas, wet areas, or areas exposed to materials that may deteriorate the structural floor slab. Floor depressions shall be reviewed for equipment requirements to allow for ease of movement of equipment. Floor slabs shall slope to accommodate drainage, and pits shall be provided in cage wash areas. Suitable protection of the concrete and reinforcing shall be considered in high-temperature cage wash areas, and areas employing salt water in conjunction with their research.

### C. Security:

Security level of design for all biomedical laboratories and animal research facilities shall result from project specific risk assessment. The A/E shall use the existing baseline Threat Assessment, provided by DPSM, for the preparation of an updated Threat Assessment.

### C.1 Progressive Collapse:

Progressive collapse resistance shall be considered in the structural design of the facility and provided in accordance with GSA design requirements.

Prevention of Progressive Collapse: The project manual shall require the A/E to indicate and specify, if and where expansion anchors will be used in tension on the project. The A/E shall indicate the "maximum load" that type of anchor will be required to carry in tension. The Construction Contractor shall initially test at least one of ten of those anchors, randomly selected by the NIH. A device, of the Contractor's design, shall suspend a load from each of the designated anchors. The load shall be 3 times the "maximum load" and left for 24 hours. The contractor shall record the results and provide a copy of the report to the NIH. If a test anchor fails to maintain the installed status, more anchors shall be tested to the satisfaction of the project engineer that the anchors are safe.

### D. Use of Recycled Materials in Concrete:

The NIH encourages the use of recycled materials in concrete if cost effective and unless a product is not available competitively within a reasonable timeframe or does not meet appropriate performance standards. Concrete containing coal fly ash or ground granulated blast furnace slag can be considered for NIH projects, EXCEPT in animal facilities.

## 5-1-20 Design Information

### A. General References

During the planning and design phase, the most cost-effective, functional and aesthetic structural design should be developed. NIH campus buildings should meet all current building codes and ordinances. These include, but are not limited to, the latest editions of the following:

- International Building Code, International Code Council, 5203 Leesburg Pike, Suite 708, Falls Church, VA 22041-3401
- Building Code Requirements for Reinforced Concrete, ACI 318, American Concrete Institute, Detroit, MI
- Manual of Steel Construction ASD, American Institute of Steel Construction, Chicago, IL

- Building Code Requirements for Masonry Structures, ACI 530; and Specifications for Masonry Structures, ACI 530.1, American Concrete Institute, Detroit, MI
- Minimum Design Loads for Buildings and Other Structures, ASCE 7, American Society of Civil Engineers, New York, NY
- National Design Specification for Wood Construction; and National Design Specification Supplement, National Forest Products Association, Washington, DC

## 5-1-30 Design Document Requirements

### A. Structural Plans (Design Development and Contract Documents)

Floor framing plans, sections, roof framing plan, roof penetration details, column and beam schedules, miscellaneous details, and cover sheet requirements.

### B. Specifications (Outline and Detail Performance Specifications)

Outline specifications shall be developed at the design development stage and detail performance specifications shall be developed at the contract document stage.

### C. Cost Estimates (Systems and Quantity Takeoff Estimates)

Systems cost estimates shall be developed at design development stage and quantity takeoff estimates shall be developed at the contract document stage.

# Section 5-2: Structural Load Requirements



## 5-2-00 Design Requirements

### A. Live Loads:

Floor design live loads shall be simplified to accommodate future load occupancy changes. Generalized live load categories shall be applied to large areas. Compliance with the IBC occupancy/use minimum concentrated live loads is required. The design live loads shall be indicated on all structural plans.

For renovation projects, the live loads of adjacent existing areas shall be noted on the structural plans to aid the contractor in determining construction live loads in staging areas or areas to be accessed during construction or demolition. Specialized equipment loads and requirements shall be verified with the equipment manufacturer. The following minimum live loads shall be used except when higher loads for specific projects are required to meet program requirements:

Minimum Live Loads for Individual Types of Space

| Type of Space | Min Live Load (kPa) |
|---|---|
| Animal Research Facility | 5.0 |
| Animal Research Facility With Primates | 6.0 |
| Aquatic Facilities | 6.0 |
| Cagewash | 10.0 |
| Catwalks (exclusively walking surfaces) | 2.0 |
| Conference Rooms | 6.0 |
| Dedicated Areas for Compact File Systems | 12.0 |
| Equipment Imaging Spaces | 10.0 |
| Frozen Storage, Refrigeration Areas | 10.0 |

| Type of Space | Min Live Load (kPa) |
|---|---|
| Interstitial Platform (exclusively walking surfaces) | 2.0 |
| Laboratories | 5.0 |
| Loading Docks And Receiving Areas | 12.0 |
| Mail Room | 10.0 |
| Mechanical Areas (or weight of equipment if greater) | 7.5 |
| Offices | 5.0 |
| Operating Rooms | 5.0 |
| Reception Lobby Areas | 6.0 |
| Roofs (not designed for future expansion) | 2.0 |
| Stairs, Corridors | 5.0 |
| Standard File Rooms | 7.5 |
| Storage Rooms | 7.5 |
| Toilet Rooms | 5.0 |

## A.1 Live-Load Reduction:

Columns supporting a building roof level shall not be subjected to live-load reduction. The A/E shall comply with the IBC for live-load reduction, or the current model building code for the area, whichever is more stringent. For the structural design evaluation of sound existing buildings for renovation and re-use, the A/E may use the allowable live-load reduction allowed by the building code of the year during which the building was originally constructed, unless engineering judgment deems the live-load reductions too liberal.

## B. Dead Loads:

The building shall be designed to support the actual weights of all materials. These include structural materials, finishes, ceilings, partitions, shielding, piping, and ductwork. Assumed weights shall be indicated on the design documents

## B.1 Superimposed Dead Loads:

The design of the structure shall specifically account for vertical loads imposed on the building by systems or elements that do not act as part of the primary structural system but are not expected to move or change during the life of the structure (typically mechanical systems, ceiling systems, and the exterior façade) and shall include anticipated superimposed dead loads in any seismic load calculation. The following loads shall be used as a minimum in the design of the facilities:

Minimum Superimposed Dead Loads for Building Systems

| Building System | Min Dead Load (kPa) |
|---|---|
| Ceilings | 0.25 |
| Cement Plaster Ceiling | 2.50 |
| Suspended MEP Systems | 0.75 |
| Partitions (Excluding CMU & Concrete) | Included in Live Load |
| Roofing | 1.00 |
| Brick Façade with Backup | 3.00 |
| Curtain wall | 1.00 |
| CMU Partition Walls | 2.50 |

## B.2 Hanging Loads:

Loads exceeding 20 kg shall not be suspended from metal decking. All ductwork, piping, and so on shall be suspended directly from the structural steel framing or supplementary steel members. Loads suspended from steel joists shall be suspended from the top chords unless structural analysis allows otherwise.

For new concrete construction, cast-in inserts shall be considered for hanging items in mechanical rooms, attaching overhead lights and equipment in operating rooms, or hanging any heavy loads.

For plaster ceiling panels, an area of 14 $m^2$ shall not be exceeded without a structural separation from an adjoining panel section. Loads exceeding 2kPa shall be suspended independently of suspended ceiling construction.

For existing construction, expansion anchors shall not be used to carry significant load in tension, except with written approval of a registered professional engineer for the specific

application. The A/E shall specify installation of anchors with drill bits and equipment recommended by manufacturer of the anchors, including required evidence indicating that contractor personnel were instructed in the correct installation procedures of that manufacturer's anchors.

## B.3 Thrust Blocks:

The Structural Engineer and the HVAC/Plumbing Engineers, in close coordination, should design the thrust blocks needed for the piping systems inside the building.

## C. Vibration:

The structural system shall be stiff to the extent that any transmitted vibration occurs at high frequencies, as these are more easily dampened with instrumentation vibration dampening systems and isolation tables than vibrations occurring at lower frequencies. To control vibration transmitted into laboratory and animal research facility space, the A/E shall address the following items:

- Design a structural system with short column spacing.
- Isolate laboratory spaces from sources of vibration.
- Locate vibration-sensitive equipment on grade-supported slabs.
- Locate vibration-sensitive equipment near columns on framed floors.
- Avoid combining corridors and laboratory spans in the same structural bay on framed floors.

The table below indicates the recommended floor vibration velocity limits, for various sensitive space us-ages, and shall be met using the following criteria:

- Walking pace for a closed corridor (a corridor with walls on both sides and doors on either or both wall) shall be 90 steps/minute.
- Walking pace for open or "ghost" corridor (a corridor with a wall on one side, with or without doors, and the ends of laboratory benches or other laboratory paraphernalia on the opposite side) shall be 75 steps/minute.
- Walking pace for cross aisles (walkways between laboratory benches) shall be 60 steps/minute.

See Chapter 6, Section 6-12 Noise and Vibration

| Space or Equipment Type | Vibration Velocity Limits (µm/s) | Structural Criterion "kfm" (kips/in-sec) |
|---|---|---|
| Animal research facility | 100 | 3,200 |
| Bench microscopes greater than 400x magnification (mag) & optical equipment on isolation tables | 25 | 12,800 |
| Bench scopes up to 100x mag | 50 | 6,400 |
| Bench scopes up to 400x mag | 25 | 12,800 |
| Electron microscope greater than 30,000x mag, mass spectrometers, cell implant | 6 | 51,200 |
| Electron microscopes up to 30,000 x mag | 12 | 25,600 |
| Eye surgery, neurosurgery | 25 | 25,600 |
| General laboratory | 50 | 6,400 |
| Laser-based optical systems | 12 | 25,600 |
| Microscope core (EM laser) | 25 | 12,500 |
| MRI and NMR - slab on grade (SOG) | SOG | -- |
| Ordinary surgery | 25 | 12,500 |
| Rodent behavioral & holding rooms | 50 | 6,400 |
| Super microscope - very low – SOG | SOG | -- |

The manufacturer of equipment sensitive to vibration shall verify that these limits are acceptable for their equipment to work within the DRM required limits. A person's weight combined with the walking speed is assumed to define an acceptable vibration number. Ambient horizontal vibration shall be less than 20 micro meters per second.

Areas required to be sensitive against vibration transmission shall be designed in consideration of adjacent equipment, other sources of vibration, and operations. The A/E shall contract with a consultant specializing in vibration analysis and control, not associated with the design A/E and acceptable to the NIH, shall be retained for all laboratory and animal research facility construction to perform an analysis of vibration response of the structure with specific vibration recommendations. The consultant shall cooperate with the structural engineers for information regarding the building design and its anticipated response to wind

forces. The consultant shall address issues relative to vibration sensitive equipment and specialized functions such as nuclear magnetic resonance (NMR), neurosurgery, eye surgery, and mass spectrometry. Consideration shall also be given to vibration of floor-framing systems caused by mechanical and electrical equipment such as pumps, chillers, fans, emergency generators, and transformers; and other sources such as foot traffic, parking garage traffic, and movement of heavy equipment. Steel structures shall not be considered for use in design relative to vibration without analysis.

## 5-2-10 Design Guidance

### A. Wind Loads:

The building shall be designed to comply with the IBC for the geographic basic wind and exposure category.

### B. Seismic Loads:

Seismic loads shall be determined using the provisions of the IBC for the seismic area in which the project is located.

### C. Snow Loads:

The building shall be designed for the geographic ground snow load for the area indicated by the IBC. The effects of sliding and drifting snow shall be incorporated in the design.

# Section 5-3: BSL3 & ABSL3 Biocontainment



## 5-3-00 Design Requirements

The primary structural systems for NIH BSL3 and ABSL3, facilities shall be designed and constructed to meet the strength and serviceability requirements of the facilities' program. The structural systems shall be designed to meet life safety requirements while resisting gravity and lateral load combinations required by the building code. The structural systems shall also meet applicable serviceability criteria allowing building occupants to use the facility as intended while resisting code level load combinations. The framing systems shall have operational demands placed upon them that exceed those for conventional construction, including:

- Providing a suitable substrate for containment envelope in laboratory area.
- Minimizing crack propagation in the structural substrate of containment areas.
- Providing a surface suitable for application of coating systems.
- Providing adequate shielding for specific instrumentation and imaging equipment to be utilized in the facilities.
- Providing a structural framing system familiar to local contractors to ensure construction quality.

### A. Standards of Quality:

The standards for quality for NIH BSL3 and ABSL3 facilities shall be the current and most rigorous industry standards applicable to laboratory construction. The standard of quality shall be specified by compliance with various codes, standards, and guidelines that have been produced and published by the industry and by the user.

### B. Specifications:

The latest accepted material and industry specifications shall apply to the design and construction of these facilities. For structural concrete systems material specifications published by the American Concrete Institute (ACI), the Concrete Reinforcing Steel Institute (CRSI), and the Post-Tensioning Institute (PTI) shall be utilized in the design and construction process. Specifications include the most recent edition of:

- *"Control of Cracking in Concrete Structures,"* ACI 224R, American Concrete Institute, Detroit, MI.
- *"Specification for Structural Concrete,"* ACI 301, American Concrete Institute, Detroit, MI.
- "Environmental Engineering Concrete Structures," ACI 350, American Concrete Institute, Detroit, MI.
- *"Concrete Structures for Containment of Hazardous Materials,"* ACI 350.2R, American Concrete Institute, Detroit, MI.

## C. Serviceability:

The building structure shall be designed to prevent structure deflections and movements that shall increase the cost of interior finishing, cause discomfort or concern to the occupants, increase wear or damage to exterior building systems, or affect facility operations. Mini-mum serviceability criteria shall be utilized for NIH BSL3 facilities as follows:

## D. Live Loads:

No live load reduction is permitted.

## E. Deflections:

Total Calculated Deflections

| Calculated Deflection under Loading Types | Total Calculated Deflection | Max Deflection (mm) |
|---|---|---|
| Calculated deflection for design dead load | <Span length/360 | ≤ 25 |
| Calculated deflection for design live load | <Span length/360 | ≤ 25 |
| Total calculated deflection of floor system for total design load including time effects | <Span length/240 | ≤ 40 |
| Vertical deflection for super-imposed dead loads & live loads for structural supporting masonry | =Span length/600 | =Span length/600 |

## F. Shielding:

Provide adequate shielding for instrumentation or imaging equipment that emits electro-magnetic and radiation waves to ensure the safety of personnel and accurate operation of equipment.

# 5-3-10 Design Guidance

## A. Importance Factors:

NIH BSL3 facilities shall be classified as Category III buildings per the IBC. Importance factors consistent with this classification shall be used in conjunction with the IBC and ASCE-7.

## B. Loads:

NIH BSL3 facilities shall be designed per Section 5-2 “Structural Load Requirements” of this chapter except for the following:

### B.1 Snow Loads:

Loads shall be determined using the provisions of the design standard ASCE 7 as referenced by the IBC. The ground snow load value shall be determined from the contour maps. This value shall be modified by various factors stipulated by the design standard to yield the design snow load for the facilities.

### B.2 Wind Loads:

Wind loads shall be determined using the provisions of the design standard ASCE 7 as referenced by the IBC. The basic wind speed value shall be determined from the contour maps. This value shall be modified by various factors stipulated by the design standard to yield the design loads for the facilities.

### B.3 Seismic Loads:

Seismic loads shall be determined using the provisions of the IBC. Seismic acceleration values may be developed using the contour maps in Chapter 16 of the IBC or may be developed by utilizing a site specific seismic acceleration study as permitted by Chapter 16 of the IBC. The site specific seismic acceleration study shall be performed by a qualified geotechnical engineer. The geotechnical engineer shall classify the site in accordance with the IBC based upon shear wave velocity using boring logs and other appropriate investigation techniques.

### B.4 Drift:

The calculated building drift when subjected to code level wind loads is less than the floor height/400. The calculated building drift when subjected to code level seismic loads meets the requirements of chapter 16 of the IBC.

## 5-3-20 Design Information

The A/E shall refer to Sections 2-5 and 2-6 in Chapter 2 and the preceding sections of this chapter and make a determination of all applicable provisions that are to be incorporated into the design of the biocontainment facility.

## 5-3-30 Design Document Requirements

### A. Structural Plans (Design Development and Contract Documents)

Floor framing plans, sections, roof framing plan, roof penetration details, column and beam schedules, miscellaneous details, and cover sheet requirements.

### B. Specifications (Outline and Detail Performance Specifications)

Outline specifications shall be developed at the design development stage and detail performance specifications shall be developed at the contract document stage.

### C. Cost Estimates (Systems and Quantity Takeoff Estimates)

Systems cost estimates shall be developed at design development stage and quantity takeoff estimates shall be developed at the contract document stage.

# HVAC

6



# Section 6-1: HVAC Design Considerations



## 6-1-00 Design Requirements

### A. Heating, Ventilation, and Air-Conditioning Systems for Research Laboratories and Animal Facilities:

Heating, ventilation, and air-conditioning (HVAC) systems for Research Laboratories and Animal Facilities shall be designed to maintain the space temperature and humidity at the required set point. These systems shall automatically adjust, as necessary, to respond to varying space cooling demands in laboratories and animal facilities. Air-change rates, temperature and humidity shall be closely monitored and controlled on a continuous basis. The System shall provide adequate ventilation to remove fumes, odors, airborne contaminants, and to safely operate fume hoods continuously. They shall be designed to maintain relative pressure differentials between spaces to prevent of cross contamination. Space background noise, generated by HVAC systems, shall be maintained within the levels prescribed within this document. HVAC systems shall be reliable, redundant and operate without interruption while being efficient to operate, both in terms of energy consumption and from a maintenance perspective.

Federal energy conservation standards shall be achieved. An energy monitoring and control system shall be provided. This document outlines the basis of design and energy conservation compliance requirements. During the design phase, studies shall be conducted to determine the feasibility of utilizing heat-recovery systems in research laboratory and animal facility buildings.

Laboratory spaces shall meet the requirements in the “Biosafety in Microbiological and Biomedical Laboratories” published by Center for Disease Control and Prevention and NIH.

Animal Facilities shall meet the requirements in the “Guide for the Care and Use of Laboratory Animals” published by the Institute of Laboratory Animal Resources.

## B. Outdoor Design Conditions:

All facilities shall be designed in accordance with the climatic conditions listed in ASHRAE Handbook of Fundamentals. For summer conditions, use 0.4% column (9a / 9b) dry bulb (DB) / mean coincident wet bulb (MCWB) temperatures. For winter conditions, use 99.6% column (3a) DB temperature. Summer mean coincident wind speed (MCWS) shall be 0.4% DB column (11a). Winter MCWS shall be 99.6% DB column (6a)

Sizing of evaporative type cooling towers shall be based on 1°C (2°F) higher than the WB temperature shown in the 0.4% column (10a) shown in the ASHRAE Handbook of Fundamentals.

All outdoor air-cooled condensing equipment shall be designed and selected on the basis of 35°C (95°F) ambient temperature.

## B.1 Outdoor Design Conditions (Bethesda and Poolesville):

Equipment to be located in the main Bethesda campus and the Poolesville facility shall be designed in accordance with the following table:

| Outdoor Design Conditions | | |
|---|---|---|
| Season | Temperature °C (°F) | Wind Speed m/s (mph) |
| Summer | 35.0 (95) DB, 25.6 (78) MCWB | 5.4 (12) |
| Winter | - 11.6 (11) DB | 4.8 (10) |
| Evaporative cooling | 26.7 (80) WB | n/a |

All outdoor air-cooled condensing equipment shall be designed and selected on the basis of 35°C (95°F) ambient temperature

## C. Energy Conservation:

The A/E shall utilize the latest edition of the following energy codes and standards to design the exterior envelope and select HVAC systems, domestic water heating, electrical distribution and illuminating systems:

- ASHRAE Standard 90.1
- Energy Policy Act 2005.
- International Energy Conservation Code.

The Project Officer shall be notified when requirements of the energy conservation codes and standards cannot be satisfied due to program requirements. New construction or major renovation shall require complete HVAC and energy simulation modeling. Life cycle cost shall include capital cost factors for chillers and boilers as provided by NIH, as well as up to date energy costs.

## D. Building Design Requirements:

HVAC systems shall maintain a safe and comfortable working environment and be capable of adapting to new research initiatives. In addition, they shall be easy to maintain, energy efficient, and reliable to minimize lost research time. HVAC systems for laboratory shall include central air-handling systems utilizing 100% outdoor air, which shall also provide adequate ventilation to offset exhaust air requirements. Laboratory supply air shall not be recirculated or reused for other ventilation needs.

## D.1 Indoor Design Conditions:

Occupied spaces, unless noticed otherwise, shall be designed to maintain the following temperature and humidity levels:

| Indoor Design Conditions | | |
|---|---|---|
| Season | Temperature ˚C (˚F) | Relative Humidity % |
| Summer | 23 ± 1 (73 ± 2) | 50 ± 5 |
| Winter | 21 ± 1 (70 ± 2) | 30 ± 5 |

## D.2 Ventilation Rates:

Ventilation rates, unless noticed otherwise, shall be calculated to meet the cooling and heating loads and outdoor air requirements in accordance with ASHRAE design guidelines.

## D.3 Heating Systems:

Heating, in NIH facilities, shall be provided by the use of steam and/or heating water systems. Electric resistance heating shall NOT be used to provide heating in any NIH facility. This includes built-in small electric heaters.

## D.4 Cooling Systems:

Cooling, in NIH facilities, shall be provided by the use of chilled water/hydronic systems. The use of air-cooled, self contained refrigeration systems for building cooling coils in air-handling systems shall be avoided unless chilled water is not available

## D.5 Air Distribution Systems:

Supply, exhaust, and outside air shall be ducted for all spaces, i.e., not taken through ceiling plenums, shafts, mechanical equipment rooms, corridors, or furred spaces. The circulation of air directly between areas is not permitted, except into toilet rooms, locker rooms, and janitor's closets. Circulation may also occur between adjacent corridors into a negative pressure area or out of positive pressure areas.

Supply air distribution system shall be designed to minimize turbulence and to avoid having an impact on the performance of primary containment equipment such as chemical fume hoods and BSCs.

- Air outlets shall not discharge into the face of fume hoods or BSCs.
- Exhaust grilles and registers shall be located away from supply air diffusers in a manner that creates uniform, low velocity airflow across the room.

Plenums and air shafts for distribution of supply or exhaust air is prohibited in NIH laboratories and non-laboratory buildings. Common outdoor air ductwork may be permitted for outdoor air intakes to multiple air-handling units due to space constraints and building configuration

Corridors shall be provided with conditioned air to maintain design temperatures and as required to make up air for negatively pressurized rooms opening directly to the corridor. The quantity of conditioned air to the corridors shall be sufficient to maintain an overall positive building pressure

## D.6 Anterooms:

Anterooms are typically located between the laboratory/isolation/protected room and the corridor. The anteroom has two sets of doors, one door to the laboratory/isolation/protected room and one door to the corridor. These two doors are interlocked so that only one door can be opened at a time. Depending on the type of isolation required, the anteroom may be positive, negative or neutral. The use and type of anterooms needs to be reviewed with NIH/DTR and NIH/DOHS.

Anterooms shall be provided with both supply and exhaust air grilles. In addition, anterooms shall be provided with dedicated supply and exhaust air terminal units/boxes, which would permit the reconfiguration of the anteroom to accommodate program changes.

Typically, room differential pressure sensors are provided to monitor the pressure differential between the ante room, the laboratory/isolation/protected room and the corridor. Room

pressure differential is set to maintain a minimum of 2.5 Pa (0.01 in wg). In some cases, room differential pressures may be as high as 12.5 Pa (0.05 in wg) or greater. Required room differential pressure needs to be reviewed by NIH/DTR and NIH/DOHS.

## D.7 Program Equipment:

The selection and use of program equipment such as refrigerators, freezers, centrifuges, autoclaves, glassware washers, BSCs, fume hoods, etc. shall be established early in the design phase so that mechanical and electrical systems can be designed to support specific equipment requirements.

Program equipment shall comply with NFPA, OSHA, ANSI, NSF, NIH Fume Hoods Specifications requirements and other applicable standards. Equipment selected shall not contain asbestos, lead or mercury.

The A/E shall obtain equipment requirements so that heat rejection, electrical usage, and other utility consumption data are included in the design of the HVAC systems. Equipment space requirements shall be closely reviewed, and layouts shall allow for access to all piping, wiring, and ductwork connections, easy cleaning, maintenance and repairs.

Mechanical systems shall be designed and detailed so that they do not induce harm to or impede the operating efficiency of program equipment. Pressure regulators, safety relief valves, gravity drainage facilities, temperature controls, and backflow protection devices shall be provided as required to protect equipment.

The building temperature control systems / Building Automation Systems (BAS) shall not be use to operate/control program equipment. The complete control and operation/maintenance strategy for program equipment shall be closely reviewed against program requirements and with program users.

## D.7.a Flammable Storage Cabinets:

Flammable storage cabinets shall not be vented and shall not be located underneath fume hoods.

## D.7.b Corrosive Storage Cabinets:

A ventilated corrosive storage cabinet shall be provided in each laboratory. Typically, these are located underneath fume hoods if present.

## D.7.c Biological Safety Cabinets:

At NIH, biological safety cabinets (BSC) are typically Class II, Type A1 or Type A2, which shall NOT be hard ducted to the building exhaust air system, nor shall thimble connections be used.

BSC Class I, Class II-B1 and Class II-B2 are also used in NIH facilities. These particular types of BSCs shall be hard ducted to a dedicated building exhaust air system. In addition, BSC Class II-B1 and Class II-B2 shall be factory provided with means of shutting down the BSCs internal fan, whenever the static pressure, in the building exhaust air system connected to the BSC, drops below the required set point. This is required to avoid having a positive BSC and positive exhaust ductwork. This will prevent the release of hazardous products into the laboratory space. Whenever multiple BSC of this type are connected to the same system, each BSC shall be provided with a dedicated exhaust type air terminal unit. This will ensure the proper exhaust air amount is maintained through each BSC. Building exhaust air systems serving these BSCs shall include provisions for increasing the systems static pressure to compensate for loading of the exhaust HEPA filters within the BSC, i.e. VFDs.

Rooms with ducted BSCs shall be provided with an additional room exhaust air grille connected to a dedicated exhaust air terminal unit. Whenever the manual isolation damper associated with the BSC is closed, during the certification process of the BSC, the room ventilation system shall automatically adjust in order to maintain the negative pressure in the laboratory.

Regardless of class and type, all BSCs, at NIH, shall be provided with unit mounted HEPA filtration of the exhaust air prior to its discharge to the room space or to the outdoors. All Class II BSCs shall comply with Standard NSF-49 developed by the National Sanitation Foundation (NSF).

Projects requiring the use of BSCs, regardless of class or type, shall be reviewed and approved by the NIH/DOHS and NIH/DTR during the design phase of the project.

## D.7.d Fume Hoods:

Fume hoods may be variable air volume (VAV) or constant air volume (CV) type. Although the use of VAV hoods is highly recommended, the decision shall be based on a comprehensive lifecycle cost analysis that accounts for all system features required by NIH. Fume hoods to be used in NIH Facilities must meet the following criteria:

| Fume Hood Types | | | |
|---|---|---|---|
| Fume Hood | Type | Nominal Hood Width mm (in.) | NIH Specification Section |
| Vertical Sash | Bench | 1200 (48) – 1800 (72) | 11810 (August 2004) |
| Horizontal Sash | Bench | 1800 (72) | 11820 (August 2004) |
| Combination Sash | Bench | 1800 (72) | 11830 (August 2004) |

In addition, fume hoods shall comply with the testing requirements in the following NIH documents:

- NIH Specification Section 15991 – On Site Testing – Constant Volume Fume Hoods
- NIH Specification Section 15992 – On Site Testing – VAV Fume Hoods
- Appendix E.3 "Fume Hood Testing and Alarm System."

Fume hoods shall be evaluated "AM" (as manufactured) under the ANSI/ASHRAE STD 110 and shall meet the following minimum performance ratings:

- Sash design position or positions: 457 mm (18 in.)
- Average face velocity: 0.51 m/s (100 fpm) (plus or minus 10%)
- Range of face velocities: No point in grid below 0.41 m/s (80 fpm) or above 0.61 m/s (120 fpm). Actual not as measured.
- Average face velocity for sash at 50%: 0.41 (80) to 0.76 m/s (150 fpm).
- Average face velocity for sash at 25%: 0.41 (80) to 1.52 m/s (300 fpm)
- Performance rating: 0.05 ppm.
- Sash movement performance rating: 0.10 ppm.
- Response time for VAV hoods: Less than 3 seconds.
- Percentage of auxiliary air supply: 0% (auxiliary air hoods are not allowed)
- Static pressure loss: Not more than 124 Pa (0.5 in. wg) at 0.51 m/s (100 fpm) face velocity.

## D.7.e Variable Air Volume Fume Hoods:

VAV fume hoods to be used in NIH facilities shall meet the following requirements:

- Fume hoods shall meet current NIH fume hood specifications.
- Fume hoods in non-containment type laboratories shall have no air-cleaning (HEPA or charcoal), except for radiological hoods.
- The laboratory shall remain under negative pressure with respect to the corridor or adjoining rooms even when the fume hood operates at the minimum exhaust air rate. When the exhaust air quantity is reduced, supply air quantity shall be reduced by the same volume.

- Laboratory minimum ventilation requirement, ACH, shall be provided even when the fume hood(s) operate in the minimum exhaust air rate position.
- Airflow monitoring/alarm devices shall be installed at each fume hood to provide the user with operating information. These devices shall monitor the following: (1) face velocity at the sash opening. (2) Sash position, and (3) pressure differential between hood and room.

Go to http://orf.od.nih.gov/PoliciesAndGuidelines/Bioenvironmental/ for additional information and applicable studies authored by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health and refer to the following articles:

- Methodology for Optimization of Laboratory Hood Containment - Volumes I and II
- NIH - Section 15991 - Onsite Testing for Constant Volume Fume Hoods - June 2006
- NIH - Section 15992 - Onsite Testing for Variable Volume Fume Hoods - June 2006

## D.7.f Low Flow and Auxiliary Air Fume Hoods:

Low flow fume hoods may be used at NIH as long as they meet ALL the requirements as outlined in the NIH / ASHRAE 110 Modified Fume Hood Testing Protocol. In addition, fume hoods shall comply with the testing requirements of the listed NIH onsite testing specification sections 15991, 15992 and Appendix E. 3 “Fume Hood Testing and Alarm System.” The face velocity of low flow hoods should *NEVER be below 0.41 m/s (80 fpm).*

Auxiliary air-type fume hoods shall NOT be used in any NIH facilities. In the event of a retrofit application, the A/E shall investigate the capacities of the existing system exclusive of the auxiliary air, and laboratory supply and exhaust system characteristics. Once it has been established that the system can support the addition or replacement of an existing fume hood, this information shall be forwarded to the project officer for approval before the design is allowed to proceed.

## D.8 Environmental Rooms:

Environmental rooms could be constant temperature cold rooms or hot rooms. These rooms shall be located to accommodate service from outside the room space. Temperature and humidity readouts shall be located inside and outside the room. Ventilation of environmental rooms, such as cold rooms, which serve as occupied functioning laboratory spaces, shall be designed in accordance to the latest issue of ASHRAE Standard 62. Environmental rooms used primarily for storage functions shall not require ducted ventilation air.

Cold rooms shall be provided with remote condensing units, which are not located directly above the room. Floor mounted condensing units are preferred. Associated, air conditioning components shall be located to accommodate service from outside the room. Condens-

ing units shall be water cooled. If air cooled condensing units are used due to the lack of hydronic cooling media, then, the temperature of the area surrounding the condenser shall not be allowed to exceed 6°C (10°F) above the temperature of occupied adjacent areas. Design consideration shall be given to ventilating and dissipating heat accumulation caused by equipment condensers.

## D.9 Equipment Room Ventilation (Non-Lab Equipment Rooms):

Equipment rooms such as mechanical, electrical, boiler, chillers, pumps, air-handling units, fans, autoclave, and cage wash equipment, etc shall be heated and ventilated as follows:

- Heating shall be provided by the use of steam or heating water. These rooms shall be heated to maintain a space temperature of 18°C (65°C).
- Ventilation systems shall be provided to maintain the space temperature to no more than 12°C (20°F) above outdoor air temperature. Additional ventilation may be required to dissipate heat generated by the equipment located in the space.
- Minimum ventilation rates shall comply with local building codes and good Indoor air quality practices and requirements.
- Containment exhaust systems shall not be used to ventilate mechanical spaces.

Electrical rooms shall be ventilated to maintain a space temperature no more than 8°C (14°F) above outdoor air temperature. Outdoor air into this room shall be filtered by using filters of 30% efficient filtration based on ASHRAE's Standard 52, atmospheric dust-spot test efficiency. If the electrical room is located within the building, and ventilation with outdoor air is not feasible, conditioned air shall be utilized to maintain the space to no more than 26°C (80°F).

Secondary switchgear rooms shall be provided with heating and cooling equipment to maintain space temperature between 18°C (65°F) and 26°C (80°F) and humidity level between 30 to 60% non-condensing to protect switchgear and electronic controls. Switchgear/transformer rooms located at the NIH Bethesda and Poolesville campuses shall be provided with temperature and humidity sensors. These sensors shall be connected to the existing Supervisory Control and Data Acquisition (SCADA) system, which is the energy monitoring system for the campus.

Hydronic piping shall not be located with in electrical rooms and secondary switchgear rooms. In the event that this can not be avoided, protection shall be added such as drip pans beneath all piping and equipment. These drip pans shall be provided with water detection alarms connected to the BAS. Hydronic piping and drip pans shall never be located over any electrical transformer, electrical panels, and switchgear.

Large equipment rooms, with significant ventilation requirements, shall be provided with multiple fans to avoid having areas with excessive accumulated heat.

Boiler rooms and rooms with combustion equipment shall be provided with a ventilation system that combines the ventilation requirements and the combustion air requirements.

Elevator machine rooms, telecommunication closets, fire alarm rooms, and other similar spaces with electronic equipment may require air conditioning instead of outdoor ventilation. The A/E shall define criteria for these spaces and design accordingly.

## D.10 Mechanical Equipment Location and Access:

Mechanical systems shall be designed in accordance with the following principles:

- HVAC, electrical, and plumbing systems shall be zoned to avoid overlapping of multiple systems over multiple buildings zones. This will help reduce building complexity during shutdowns, building trouble shutting and building renovation.
- HVAC systems shall be designed such that there are specific building zones for smoke and fire control, piping, ductwork, conduits, cable trays, and lighting. This is to include defined access and service areas/zones to all equipment. These areas/zones need to be identified in the construction documents. This needs to be particularly defined in mechanical rooms and interstitial spaces.
- Systems shall be selected to minimize the number mechanical components requiring service and maintenance.
- System components requiring frequent service and maintenance shall be located in equipment rooms or service areas and not above suspended ceilings or in occupied spaces.
- Clear and safe access shall be provided for servicing, removing, and replacing equipment.
- Sufficient instrumentation shall be specified for monitoring, measuring, adjusting, controlling, and operating at part load as well as full load.
- Equipment shall be selected and located for long-term durability, reliability, maintainability, and serviceability, so as to meet, at a minimum, the service life expectancy indicated by ASHRAE.
- Equipment shall not be located in confined, or with an access through, secured spaces.

## E. Exhaust Air Systems:

Every exhaust air system is unique and requires specific review of issues such as air quantity, filtration, construction materials, type of discharge, controls, emergency power, hours of operation, etc. In addition, exhaust air systems shall meet the following requirements:

- Exhaust air systems shall be designed to operate 24 hours per day, 7 days a week.
- Exhaust air systems shall be balanced with the AHU supply air systems.
- Capacity of exhaust air systems shall be increased by 20% to allow for future expansion.
- Electric motors and drives, associated with exhaust fans, shall be located out of the exhaust air stream.
- Electrical motors associated with exhaust fans shall be upsized by one motor size.
- Emergency Power - Exhaust air fans and systems shall be connected to the emergency electrical power system.
- Comply with NFPA 90A. Exhaust air ductwork shall not be located in the same shaft with supply air ductwork and return air ductwork.
- Positive pressurized exhaust air ductwork should be avoided. In addition, no positive pressurized ductwork segment, of any laboratory exhaust air system, shall be located in any occupied zone, including mechanical rooms. Offices within mechanical rooms are classified as occupied spaces.
- Fume hood exhaust ductwork and exhaust fans shall be constructed of corrosion-resistant material, such as stainless steel, or be coated with a protective corrosion-resistant product such as epoxy phenolic, or vinyl selected to resist the anticipated corrosive fumes.
- When combining containment type equipment into a single exhaust air system, the A/E shall obtain approval from NIH/DOHS for exhaust air compatibility.
- Exhaust air discharge and stack shall be as per section 6-2, paragraph 6-2-00.C "Location of Outdoor Air Intake and Exhaust Discharge"
- Dampers – Smoke dampers and/or fire dampers shall NOT be installed in laboratory exhaust ducts serving fume hoods, BSCs, or other containment type equipment.
- Controls - Variable and constant air volume exhaust air fans serving multiple spaces shall be equipped with VFDs for control of air flow and duct static pressure. Exhaust air from each laboratory and animal holding/support area shall be controlled by a dedicated pressure-independent air terminal air unit located in each room served.

## E.1 Dedicated Exhaust Air Systems:

Research areas shall be provided with dedicated and separate exhaust air systems from non-research functions in the building. In addition, the following systems shall be provided with dedicated and separate/independent exhaust air systems from any other exhaust air systems in the building:

- Isolation rooms. Multiple isolation rooms may be combined into a single exhaust air system
- Laboratory general research areas

- Fume hood exhaust. However, fume hood exhaust may be combined with laboratory general research exhaust but only after penetrating the last fire rated partition
- Exhaust air systems dedicated to serve BSCs
- Radioisotope/radioactive fume hoods
- Animal general research areas
- Cage washers. In addition, certain cage wash equipment may require special space configuration. The A/E shall discuss these systems with the animal program personnel.
- Ductwork serving central sterilization processing areas
- Ductwork serving areas with EtO sterilizers. EtO exhaust air systems shall meet the installation requirements set forth by USEPA. This system shall be provided with means of determining a failure of the exhaust air system and shutting down the EtO sterilizer.
- Ductwork serving spaces with battery-charging equipment
- Ductwork serving gas cylinders storage spaces.
- Ductwork serving pot washing equipment
- Toilet exhaust air systems. This is to include janitor's closets and locker rooms
- Any other function as designated by NIH/DOHS

## E.2 Redundancy:

Exhaust air systems shall be arranged with multiple manifolded fans designed to achieve N+1 redundancy and maintain the exhaust air system fully operational, at all times. Each manifolded fan shall be designed to be fully isolated while the overall system remains fully operational. In the case of single fan systems, in addition to the main fan, a standby fan shall be provided. The A/E shall review redundancy requirements for each particular system with the program user and the NIH/DOHS. Regardless of the system size, the following exhaust systems shall be provided with an N+1 redundancy:

- Isolation rooms
- Laboratory general research areas
- Fume hood exhaust
- Radioisotope/radioactive fume hoods
- Animal general research areas
- Cage washers
- Any other function as designated by NIH/DOHS

## E.3 Isolation Rooms:

Exhaust air system for isolation rooms shall be a dedicated system capable of serving negative pressure (normal isolation) rooms or positive pressure (reverse isolation) rooms. Exhaust air systems for isolation rooms dealing with highly infectious pathogens may require

bag-in/bag-out HEPA filtration. The A/E shall review filtration requirements for each particular system with the program user and the NIH/DOHS. If HEPA filtration is not required, the system shall be designed with provisions for adding the HEPA filtration in the future. This dedicated exhaust air system shall include: pressure-independent constant-volume air terminal units, roof-mounted exhaust fans, VFD for filter loading and/or for multiple rooms applications, exhaust stacks, bag-in/bag-out HEPA filters, etc.

## E.4 Exhaust Air Filtration:

Generally, exhaust air does not require filtration or scrubbing. However, in special laboratories, such as laboratories using radioisotopes or certain hazardous chemicals, the exhaust air may require special filtration before being discharged to the outdoors. The A/E shall consult with NIH/DTR, NIH/DOHS, and NIH/ Radiation Safety Branch for specific requirements. These exhaust air systems shall include provisions for accounting for filter loading and adjusting the system static pressure in order to maintain the required air flow amount. Whenever filters or scrubbers are required, they shall be located as close to the source of contamination as possible while maintaining ready access for installation, monitoring, maintenance, testing, and filter replacement.

## E.5 Wet Exhaust:

Wet exhaust air from areas such as sterilizers, autoclaves, glass washers, cage washers, and pot-washing equipment, etc shall be captured by using canopy-type stainless steel hoods at each equipment entrance and exit.

Canopy hoods shall meet the following requirements:

- The canopy hood shall be located above the door to load and unload the equipment. In the case of double sided equipment, a canopy shall be placed above each equipment door.
- Exhaust air shall be at a minimum rate of 0.254 m/s (50 fpm) capture velocity at the face of the canopy hood.
- Canopy hood design shall include a drip ledge to collect condensate steam. In large canopy hoods, collected condensate steam shall be piped to the nearest floor drain.
- Wet exhaust systems shall be separated from other exhaust air systems.
- Ductwork shall be pitched back toward the canopy hood.
- Canopy exhaust hoods shall be installed above steam vapor and heat generating equipment in both the “dirty” and the “clean” sides of the equipment.

For additional information refer to Appendix E.5 “Calculation Protocols for Canopy Hoods over Autoclaves: NIH Local Exhaust Ventilation (LEV) test Protocol”

## F. Design Requirements for Research Laboratory spaces:

HVAC systems for research laboratories shall be independent from other HVAC system in the building. These systems shall maintain a safe and comfortable environment, be adaptable, and be capable of maintaining the required environmental conditions.

Redundancy – Since research laboratories may conduct studies of long duration, which need to be performed under consistent environmental conditions in order to achieve repeatable results, the failure of the HVAC system is unacceptable. Central HVAC systems shall be provided with multiple air handling units and exhaust fans to provide redundancy and improve reliability. These systems shall be designed to include manifolded air-handling units to achieve N+1 redundancy and maintain operation at all times.

## F.1 Laboratory Indoor Design Conditions:

HVAC systems to serve research laboratories shall be designed to maintain the following indoor temperature and humidity conditions at all times:

| Indoor Design Conditions for Laboratories | | |
|---|---|---|
| Season | Temperature ˚C (˚F) | Relative Humidity % |
| Summer | 23 ± 1 (73 ± 2) | 50 ± 5 |
| Winter | 21 ± 1 (70) ± 2) | 30 ± 5 |

## F.2. Laboratory Ventilation Rates:

Ventilation rate, for research laboratories, is typically driven by three factors: fume hood demand, cooling loads, and removal of fumes and odors from the laboratory work area. The minimum outdoor air ventilation rate for laboratory space is 6 air-changes per hour, regardless of space cooling load. This minimum ventilation rate shall be maintained at all times. Some laboratories may require significantly higher ventilation rates to support fume hood demand or to cool dissipated heat from laboratory instruments and equipment.

Air Filtration – Air handling units to serve laboratory spaces shall be provided with filters upstream the supply air fans. These filters shall be 30% efficient pre-filters and 95% efficient after-filters. HEPA final filtration shall be provided in AHU to serve special laboratories where research materials are particularly susceptible to contamination from external sources. HEPA filtration of the supply air shall only be considered necessary for critical applications. It is preferred that BSCs, which include HEPA filtration, be used rather than providing HEPA filtration for the entire room. The A/E shall confirm with NIH/DTR and NIH/DOHS for the need of HEPA filtration in laboratories.

## F.2.a Ventilation in Laboratories working with Laser Equipment:

Rooms where laser equipment is used shall be properly ventilated to avoid buildup of ozone generated from laser and mercury lamps.

## F.3 Air Distribution:

Laboratory spaces shall be designed with special attention to air quality, room acoustics, supply air temperature, supply air humidity, airflow quantities, air velocity, and air diffusion and distribution within the space. In addition, space air distribution shall meet the following requirements:

- Distribution shall prevent cross contamination between individual spaces, air shall flow from areas of least contamination to areas of higher contamination potential, i.e., from "clean" to "dirty" areas.
- Air supply devices shall be located at ceiling level or close to ceiling level if located on sidewalls. Air distribution and diffusion devices shall be selected to minimize temperature gradients and air turbulence.
- Supply air devices shall be located away from fume hoods and BSC.
- Large quantities of supply air can best be delivered through perforated plate air outlets or diffusers designed for large air volumes.
- Space temperature and humidity shall be consistent in each individual room. Space temperature shall be monitored in each individual room
- Each lab space shall be provided with dedicated temperature controls. This shall include the used of dedicated air-terminal units for the supply air and the exhaust air.

## F.4 Relative Room Pressurization:

Laboratories shall be designed and air balanced so that air flows into the laboratory from adjacent (clean) spaces such as: offices, corridors, and non-laboratory spaces. The control of airflow direction, within research laboratory spaces, helps reduce the spread of odors, toxic chemicals, and air-borne contaminants as well as protect personnel from toxic and hazardous substances, and protect the integrity of experiments. In these facilities, the use of the once-through air-flow principle is based on: (1) Use of 100% outdoor air to provide all the room air to be exhausted through laboratory spaces and laboratory containment equipment; (2) Size the exhaust air system to handle the simultaneous operation of all laboratory spaces and all laboratory containment equipment, and (3) Directing air flow from low hazard areas to high hazard areas at all times. Air supplied to the corridor and adjacent clean spaces shall be exhausted through the laboratory to achieve effective negative pressurization. Construction Documents shall include a complete start-up and commissioning plan including procedures that address indoor air quality requirements.

Laboratory spaces shall remain at a negative air pressure in relation to corridors and other non-laboratory spaces. Typically, these systems are designed to maintain 47 L/s (100 cfm) air flow from the corridor into each lab module. Administration areas in laboratory buildings shall always be positive with respect to corridors and laboratories. Supply air distribution for corridors shall be sized to offset transfer air to laboratories while maintaining an overall positive building pressure.

Amount of supply air flow to laboratory spaces is to meet the cooling loads requirements as well as the exhaust air requirements. Typically, the exhaust airflow requirements would exceed the cooling loads requirements. In these situations, the supply air flow would need to be increased to makeup the difference between the cooling air flow and the required exhaust air flow. In cases where the cooling load airflow requirements exceed the required exhaust air rate requirements, supplemental cooling units may be required.

Special laboratories such as, genome DNA processing rooms, tissue culture laboratories, clean laboratories, etc, may require a different type of relative room pressurization. Some special laboratories may require positive air pressure in relation to adjacent spaces. In these cases, the use of a personnel entry or anterooms shall be used. These special applications need to be reviewed by NIH/DTR and NIH/DOHS.

Loading docks and receiving areas shall be maintained as positive to the outdoors and negative to the building to prevent the infiltration of vehicle fumes.

## G. Design Requirements for Animal Research Facilities:

HVAC systems for animal research facilities shall be independent from other building HVAC systems. These systems shall maintain a safe and comfortable environment for animals, be adaptable, and be capable of maintaining environmental conditions in any of the holding rooms for any of the species anticipated to be housed in the facility.

Redundancy – Since most animal studies are of long duration, they shall be performed under consistent environmental conditions in order to achieve repeatable results. Thus, the failure of the HVAC system is unacceptable. Central HVAC systems shall be provided with multiple air handling units and exhaust fans to provide redundancy and improve reliability.

Some rooms may be designated as “hooded rack” type rooms having a housing chamber with sash fronts similar to a walk-in fume hood or individual air recycle systems of the laminar-flow type. Unit directional flow, laminar-flow type systems for any of these rooms may also be required.

## G.1 Indoor Design Conditions:

Animal support facilities shall be designed to meet the following indoor temperature and humidity conditions:

| Indoor Design Conditions in Animal Support Areas | | |
|---|---|---|
| Season | Temperature ˚C (˚F) | Relative Humidity % |
| Summer | 23 ± 1 (73 ± 2) | 50 ± 5 |
| Winter | 21 ± 1 (70 ± 2) | 30 ± 5 |

Ideally, all animal-holding rooms shall be capable of housing all type of species. The HVAC system shall also be capable of maintaining the full range of requirements for all anticipated animal populations. The temperature range required to accommodate most commonly used research animals is 18˚C (65˚F) to 29˚C (84˚F) controlled to plus or minus 1˚C (2˚F). The ranges do not represent acceptable fluctuation ranges. The humidity shall be between 30% and 70% and normally controlled to 50% plus or minus 5%. These ranges can be narrowed when the species anticipated have similar requirements.

Animal-holding areas shall be maintained, at the design conditions, at all times. Design conditions shall be satisfied under all load conditions between the various holding areas.

| Indoor Design Conditions in Animal Housing Facilities | | |
|---|---|---|
| Species | Temperature (1) ˚C (˚F) | Relative Humidity % |
| Mouse | 18 (65) – 26 (79) | 35 ± 5 (3,4) |
| Hamster | 18 (65) – 26 (79) | 35 ± 5 (3,4) |
| Guinea Pig | 18 (65) – 26 (79) | 40 – 70 |
| Rabbit | 16 (60) – 20 (68) | 40 – 70 |
| Dog and Cat | 16 (60) – 29 (84) | 30 – 70 |
| Nonhuman Primate | 16 (60) – 29 (84) | 45 – 70 |
| Chicken | 16 (60) – 27 (80) | 45 – 70 |
| Amphibians | Note 2 | Note 2 |
| Aquatics (zebra fish) | 26 (78) - 29 (84) | 50 - 70 |
| Reptiles | Note 2 | Note 2 |
| Insects | Note 2 | Note 2 |

Notes:

*(1) The A/E has the option of either designing for the full range listed in each animal species or, may after consultation with the facility users, choose a narrower range expected to meet present and all known future requirements.*

*(2) To be determined by the user. These space temperatures are research dependent.*

*(3) Refer To: "Ventilation Design Handbook on animal research facilities using static Microisolators"; Volumes I and II, November 1998, Farhad Memarzadeh, PhD, P.E., NIH – Office of the Director, ORF Publication, Bethesda, MD.*

*(4) Refer To: ASHRAE 2005 Fundamentals Handbook, Chapter 10 "Environmental Control For Animals and Plants".*

Some laboratories within the animal facility conduct special research requiring unique temperature and humidity ranges and control. These special cases shall be evaluated and provided for on a case-by-case basis. The HVAC system shall be designed to accommodate these unique conditions as they occur.

## G.2 Ventilation Systems in Animal Research Facilities:

Ventilation systems in animal research facilities shall be designed in consideration of many factors such as:

- Animal species and their population
- Required minimum ventilation rate
- Recommended ambient temperature and humidity
- Heating and cooling loads within animal rooms
- Heat gain produced by the animals
- Use of microenvironments and the different ventilation methods in animal cages
- Use of fume hoods and/or BSCs
- Animal cage cleaning methods
- Animal examinations method
- Airborne contaminants
- Institutional animal care standards, as applicable to animal facilities.

Ventilation rates, within each individual room, may vary depending of the actual animal specie in each room. The following table shows a typical ventilation rates for various animal species:

| Ventilation rates in Animal Research Facilities (1) | |
|---|---|
| Facilities | Minimum Air Changes per Hour (2) ACH |
| Small Animal, Static Cage/Rack | 15 |
| Small Animal, Ventilated Cage/Rack | 10 |

| Ventilation rates in Animal Research Facilities (1) | |
|---|---|
| Facilities | Minimum Air Changes per Hour (2) ACH |
| Large Animal | 15 |
| Aquatics (zebra fish) | 6 (3) |
| Office / Administration Support | 6 (4) |
| Laboratories | 6 |

*Notes:*
*(1) Ventilation rates refer to 100% outside air*
*(2) Or higher to support fume hood and BSC demands and high heat loads*
*(3) Typical ventilation rate ranges from 6 to 9 air changes per hour*
*(4) Or 9 L/s (20 cfm) per person, whichever is greater*

Ventilation systems in animal research facilities shall meet the following requirements:

- Rooms shall be designed to avoid drafts which could adversely affect animal health
- Reduce airborne animal hair and particulate count.
- Minimum ventilation rate for animal housing and treatment facilities shall be in accordance with ASHRAE HVAC Applications Handbook, chapter “Laboratories”, ASHRAE Fundamentals Handbook, chapter “Environmental Control for Animals and Plants”, and the Institute of Laboratory Animal Resources "Guide for the Care and Use of Laboratory Animals"
- Air re-circulation within animal facilities is prohibited.

Air filtration - In addition to the typical pre-filtration and filtration normally used in air-handling units, final filtration is generally provided in air-handling units serving animal areas. This final filtration is to remove particulate and other contaminants, which can be generated within the air-handling equipment itself. Filter efficiency of final filters varies from 95% to 99.99% (HEPA). The Design Engineer shall review the specific Program of Requirements to establish specific filtration criteria.

## G.2.a Microenvironments:

Ventilation rates in animal facilities are typically 10 to 15 outdoor-air changes per hour (ACH). This practice has also been used for secondary enclosures (animal cages/microenvironments) and is considered to be an acceptable general practice. Although it is effective in many animal-housing settings, this practice does not take into account the range of possible heat loads; species, size and number of animals involved; type of bedding or frequency of cage-changing; the room dimensions; or the efficiency of air distribution from the secondary to the primary enclosure (animal room). In some situations, high flow

rates may over ventilate a secondary enclosure that contains few animals and waste energy or by under ventilating, a secondary enclosure that contains many animals, which would allow heat and odor to accumulate.
For additional information, refer to ASHRAE, 2007, HVAC Applications handbook and to the Institute of Laboratory Animal Resources, NRC, 1996, Guide for the Care and Use of Laboratory Animals.

System connections to microenvironments shall be designed to maintain manufacturer's specified criteria. For rooms housing animal ventilated racks, it is recommended, that the ventilation system be sized by adding the airflow required for the animal cooling/heating loads, of fully loaded ventilated racks, to the airflow required for other room cooling/heating loads such as lights, people, equipment, etc. This airflow shall be compared with the manufacturers recommended airflow and the larger airflow amount shall be used. The A/E shall evaluate all anticipated combinations of animals and cage systems; calculate supply air demands for make-up air, ventilation rates, cooling demand and heating demand; and design for whichever criteria results in the highest airflow demand.

Go to http://orf.od.nih.gov/PoliciesAndGuidelines/Bioenvironmental/ for additional information and applicable studies, authored by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health, and refer to the following articles:

- Comparison of Environment and Mice in Static and Mechanically Ventilated Isolator Cages with Different Air Velocities and Ventilation Designs
- Investigation of Static Microisolators in Wind Tunnel Tests and Validation of CFD Cage Model
- Mass Generation Rates of Ammonia, Moisture, and Heat Production in Mouse Cages with Two Bedding Types, Two Mouse Strains, and Two Room Relative Humidities
- Ventilation Design Handbook on Animal Research Facilities Using Static Microisolators - Volumes I and II
- Ventilation Design in Animal Research Facilities Using Static Microisolators

## G.3 Room Air Distribution:

Animal facilities shall be designed with special attention to air quality, room acoustics, supply air temperature, supply air humidity, airflow quantities, air velocity, and air diffusion and distribution within the space. In addition, space air distribution shall meet the following requirements:

- Distribution shall prevent cross contamination between individual spaces, air shall flow from areas of least contamination to areas of higher contamination potential, i.e., from "clean" to "dirty" areas.

- Air supply devices shall be located at ceiling level or close to ceiling level if located on sidewalls. Air distribution and diffusion devices shall be selected to minimize temperature differentials in the space.
- The A/E shall ensure that the system does not create drafts on the animals and that the airflow is uniform in nature.
- Where required, a provision shall also be made for high exhaust to be activated for directly exhausted racks to maximize space flexibility.
- Individual room temperature sensors, for animal holding rooms, shall be located inside the general exhaust ductwork from each room at an accessible location near the room envelope.
- Space temperature and humidity shall be consistent in each individual room. Space temperature shall be monitored and recorded in each individual room

Go to http://orf.od.nih.gov/PoliciesAndGuidelines/Bioenvironmental/ for additional information and an applicable study, authored by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health, and refer to the following article:

- Analysis of Air Supply Type and Exhaust Location in Laboratory Animal Research Facilities Using CFD

## G.4 Exhaust Air Systems:

Animal room exhaust shall be filtered at the room exhaust grille with a rough filter to capture hair and dander. This is to be accomplished by providing air filter tracks in the face of the room exhaust air grille. Filters shall be 25 mm (1-in.) throwaway type. Whenever feasible, exhaust air grilles with face mounted air filters shall be located at 300 mm (12-in.) above finished floor.

Exhaust air from animal rooms shall be discharged outdoors without recirculation into any other room. For protection of personnel and to minimize the potential for cross contamination of animals, the direction of airflow shall be inward to the animal rooms, at all times. Where protection of the animals from possible contamination is required, consideration should be made of providing ventilated airlocks for the animal rooms. The use of filtered isolation cages may also be considered. Architect/Engineers should consult with animal facility personnel with regard to the specific requirements for protection of animals.

In cage wash facilities, the “dirty,” “clean,” and cage washing equipment, including associated mechanical supporting equipment area, shall be physically separated from each other, including equipment pits.

## G.4.a Necropsy and Pathology work:

Necropsy and pathology work with infectious agents in animal research facilities shall be done within BSCs or on downdraft tables. The use and the design of downdraft tables shall be approved by NIH/DOHS. Downdraft tables shall provide an average downdraft of 0.25 m/s (50 fpm) at a height of 125 mm (5 in.) over the entire top surface of the table. [For detailed calculations on downdraft table particle capture efficiency –See Appendix H]

## G.5 Relative Room Pressurization:

Relative pressurization within animal facilities is a series of complex relationships. Some of these relationships may change as research and animal populations change. The HVAC system shall be capable of maintaining these relative pressure relationships and capable of adapting as facility utilization changes. In addition, animal spaces shall be protected against contamination from outside sources, including particulates brought in from outside by the HVAC air flow.

Animal rooms shall remain at a negative air pressure relative to clean corridors and other non-animal spaces. Clean areas of the facility including: the clean side of cage and rack washing, clean corridors, bedding dispensing, and feed preparation areas shall be positive to animal holding spaces and soiled areas. Soiled areas such as dirty service corridors, soiled side of cage and rack washing, and decontamination and waste-holding areas shall be maintained at a negative pressure.

Some areas have special pressurization requirements and shall be addressed individually. By NIH/DTR and NIH/DOHS

Animal-holding areas for transgenic or immunosuppressed populations shall be maintained at a positive pressure and may require special filtration of supply air. When these rooms are maintained at positive pressure, an anteroom or similar feature shall be placed between the animal room and the corridor.

Potentially infectious populations shall be maintained at a negative pressure to prevent contamination of other animal populations. Depending on the nature of the infectious agents involved in the research, these areas may be required to meet the design criteria for biohazard containment facilities. The use of anterooms or micro-isolator housing units may be required to maintain these special conditions.

The pressure relationships for animal care areas including treatment rooms, procedure rooms, necropsy rooms, and surgical areas require investigation by the design team with the facility user to determine project-specific requirements. The HVAC system shall be adaptable so that pressure relationships can be modified as required over the life of the facility. These applications need to be reviewed by NIH/DTR and NIH/DOHS

Dirty elevator shafts shall have negative air pressurization in relation to all surrounding areas.

## 6-1-10 Design Guidance

### A. Heating and Cooling Load Calculations:

Complete heating and cooling load calculations and a vapor drive study shall be prepared for each space within a design program and presented in a format similar to that outlined in the ASHRAE Handbook of Fundamentals. Heating and cooling load calculations are required for all projects to facilitate review and provide a reference for system modifications. Individual room calculations shall be generated and summarized on a system basis and presented with a block load to define the peak system load. Load summary sheets shall indicate: individual room's area, supply air quantity, L/s per $m^2$ (cfm), ACH, and corresponding exhaust air quantity. Calculations shall include, but are not limited to: indoor and outdoor design parameters, heat gains and heat losses, supply and exhaust requirements for central systems, and for each area of the facility, humidification and dehumidification requirements, and heat recovery.

### B. Occupancy Loads:

The A/E shall base HVAC load calculations on the expected occupancy in each space and the activity level as per ASHRAE Fundamentals Handbook.

### B.1 Animal Room Cooling Loads:

Heat generation from animals for the purpose of HVAC load calculations shall be as listed in the ASHRAE Fundamentals Handbook.

### B.2 Animal Density:

A typical 3 m (10 ft.) by 7 m (23 ft.) animal holding module shall be designed to the following animal population density:

| Design Animal Density | | | |
|---|---|---|---|
| Species | Animals per Rack | Racks per Module | Animals per Module |
| Mouse | 300 | 5 | 1,500 |

| Design Animal Density | | | |
|---|---|---|---|
| Species | Animals per Rack | Racks per Module | Animals per Module |
| Rat | 90 | 5 | 450 |
| Guinea pig | 40 | 5 | 200 |
| Rabbit | 8 | 5 | 40 |
| Cat | 8 | 5 | 40 |
| Nonhuman primate | 8 | 5 | 40 |

## C. Laboratory Equipment Cooling Loads:

The central HVAC system shall provide, as a minimum, a cooling capacity for 1,892 W (6,455 BTUH) (sensible heat) for laboratory equipment in a typical 22 $m^2$ (237 $ft^2$) laboratory module or cooling for the actual calculated load, whichever is greater. The A/E shall make a detailed and complete inventory of all laboratory equipment scheduled for installation in each space and determine the projected equipment load requirement using estimated utilization factors. Equipment utilization factors shall be indicated in the Basis of Design report. The A/E shall evaluate the following rooms used for laboratory support, often having higher than normal cooling loads, as well as evaluate the use of supplemental cooling units to remove excessive sensible loads affecting these areas, while maintaining minimum ventilation requirements:

- Common equipment rooms.
- Autoclave rooms.
- “Clean” and “dirty” cage wash rooms.
- Glassware washing rooms.
- Darkrooms.
- Special function rooms.
- Electron microscope.

## C. Lighting Loads:

Lighting loads shall not exceed the values listed below. The A/E shall base HVAC load calculations on actual lighting loads.

| Maximum Lighting Loads | | |
|---|---|---|
| Space type | Task Lighting W / person | Room Lighting (1) W / $m^2$ (W / $ft^2$) |

| Maximum Lighting Loads | | |
|---|---|---|
| Space type | Task Lighting W / person | Room Lighting (1) W / m² (W / ft²) |
| Biomedical Laboratories | 250 | 27 (2.5) |
| Animal Holding Areas | 250 | 16 (1.5) |
| Animal Procedures | 250 | 27 (2.5) |
| Offices | 250 | 14 (1.3) |
| Corridors | N/A | 11 (1.0) |

*(1) Electrical power for room lighting load does not include electrical power for task lights*

# 6-1-20 Design Information

## A. Reference Design Guidelines for the HVAC Designer

The NIH is a progressive and dynamic biomedical research institution where state-of-the-art medicine is the standard practice. To support state-of-the-art research and medical care, the facilities must also be state-of-the-art. It is the NIH intent to build and maintain the physical plant and facilities in accordance with the latest standards. It has been the NIH experience that renovation/rehabilitation of existing facilities do not lend themselves to incorporating the "latest" standards of the industry, primarily due to outdated and inadequate mechanical systems or because the planned function is incompatible with the original criteria of the facility.

The Architect and Engineer (A/E) will be alerted to this type of situation and make an evaluation early in the design stage to determine the feasibility of implementing the latest standard. The A/E should document such findings, provide recommendations, and report them to the Project Officer for a decision on how to proceed.

The A/E design firm should use and comply with, as a minimum, the latest issue of the following design and safety guidelines. In addition, the A/E should use other safety guidelines received from the NIH Project Officer or as required by program. The A/E should utilize the latest versions of guidelines available at the time the project proceeds with schematic design.

The design and safety guidelines include but are not limited to the following:

- The International Building Code
- The International Mechanical Code
- The International Energy Conservation Code

- National Fire Codes, all volumes National Fire Protection Association, (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.
- ASHRAE Handbooks and Standards - American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), Inc.: 1791 Tullie Circle, N.E., Atlanta, GA 30329.
- Industrial Ventilation: A Manual of Recommended Practice for Design, American Conference of Government Industrial Hygienist (ACGIH), 1330 Kemper Meadow Drive, Cincinnati, Ohio, 45240
- Occupational Safety and Health Standards, CFR 29, Part 1910 U.S. Department of Labor, Occupational Safety and Health Administration, (OSHA)
- Biosafety in Microbiological and Biomedical Laboratories. U.S. Department of Health and Human Services. Centers for Disease Control and Prevention and the National Institutes of Health. Washington, DC.
- Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety cabinets. U.S. Department of Health and Human Services. Centers for Disease Control and Prevention and the National Institutes of Health. Washington, DC.
- Guide for the Care and Use of Laboratory Animals. Institute of laboratory Animal Resources, Commission on Life Science, National Research Council. National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418
- Guidelines for Design and Construction of Health Care Facilities. The American Institute of Architects Academy of Architecture for Health with the assistance from the U.S. Department of Health and Human Services. The American Institute of Architects, 1735 New York Avenue, NW, Washington, DC 20006.
- Standard NSF/ANSI 49. Class II (laminar flow) biosafety cabinetry. National Sanitation Foundation (NSF). 789 N. Dixboro Road, Ann Arbor, MI 48105
- Guidelines for Laboratory Design: Health and Safety Considerations, L.J. DiBerardinis, J.S. Baum, M.W. First, G.T. Gatwood, and A.K. Seth. John Wiley & Sons, Inc, 111 River Street, Hoboken, NJ 07030-5774
- Analysis of Air Supply Type and Exhaust Location in Laboratory Animal Research Facilities Using CFD, Andrew Manning, Ph.D., Farhad Memarzadeh, Ph.D., P.E., Gerald Riskowski, Ph.D., P.E., ASHRAE Transactions 2000, Volume 106, pt 1, DA-00-14-3, Pages 877-883
- Thermal Comfort, Uniformity, and Ventilation Effectiveness in Patient Rooms: Performance Assessment Using Ventilation Indices, Farhad Memarzadeh, Ph.D., P.E., Andrew Manning, Ph.D., ASHRAE Transactions 2000, Volume 106, pt 2, MN-00-11-3, Pages 748-761
- Methodology for Optimization of Laboratory Hood Containment - Volumes I and II, November 1996, Farhad Memarzadeh, PhD, P.E., NIH – Office of the Director, ORF Publication , Bethesda, MD

- Handbook: Assessing the Efficacy of Ultraviolet Germicidal Irradiation and Ventilation in Removing Mycobacterium Tuberculosis, September 2000, Farhad Memarzadeh, PhD, P.E., NIH - Office of the Director, ORF Publication, Bethesda, MD

In addition, refer to the following documents by using the associated internet links:

- Guidelines for Research Involving Recombinant DNA Molecules. U.S. Department of Health and Human Services, U.S. Public Health Service, National Institutes of Health, Bethesda, MD
  NIH - Guidelines for Research Involving Recombinant DNA Molecules
- Laboratory Safety Monograph A Supplement to the NIH Guidelines for Recombinant DNA Research. U.S. Department of Health and Human Services, U.S. Public Health Service, National Institutes of Health, Bethesda, MD.
  NIH - Laboratory Safety Monograph: A Supplement to the NIH Guidelines for Recombinant DNA Research

## 6-1-30 Design Document Requirements

### A. HVAC Documents:

HVAC Documents shall comply with the requirements listed in Appendix B "Architect-Engineer (A/E) Checklist of Services" as stated for the different phases of the particular project. Projects phases may vary from project to project. Typically, project phases include: Pre-design, Schematic, Design Development, Construction Documents, and Construction Administration.

### A.1 Pre-design Phase:

The pre-design documents shall include a brief description of all systems proposed for the project. This is to include design criteria, methodology, redundancy, key features, and preliminary equipment sizes based on program gross square feet area. Preliminary system diagrams shall also be included. In addition, copy of preliminary calculations and preliminary cost estimate shall be included in this submission.

### A.2 Schematic Design Phase:

The Schematic design documents shall include a complete description of all systems proposed for the project. This is to include an updated design criteria, methodology, redundancy, key features, and preliminary equipment sizes based on building gross square feet area. Updated system diagrams for all systems shall also be included. In addition, copy of updated calculations and updated cost estimate shall be included

## A.3 Design Development Phase:

The Design Development documents shall include an updated description of all systems proposed for the project. This is to include an updated design criteria, methodology, redundancy, key features, and equipment sizes based room by room calculations. Copy of all calculations shall be included in this submittal. Updated system diagrams for all systems and utilities shall also be included. These diagrams shall include preliminary sizing of all pipe and ductwork mains. In addition, the following needs to be included in this submission: copy of all heating and cooling load calculations, building energy model and life-cycle cost analysis, updated cost estimate, outline specifications, preliminary construction phasing plans, ductwork and piping floor plans with sizing for all mains in every area of the building, equipment layout, control diagrams, equipment details, room pressurization analysis, control diagrams, draft specification sections for all equipment and work including controls and commissioning, and other documents indicated in other sections of this document.

## A.4 Construction Documents Phase:

The Construction Documents shall include: a copy of final room by room ventilation calculations, heating and cooling load calculations including all equipment sizing calculations, final energy model and life cycle analysis report, complete and fully sized riser diagrams and system diagrams for all systems and utilities, fully sized piping and ductwork floor plans, equipment lay out and details, control diagrams, final pressurization analysis, construction pashing plans, final specifications including controls and commissioning, final cost estimate, and other documents indicated in other sections of this document.

## A.5 Construction Administration Phase:

Construction Administration typically include: shop drawing review, provide responses to Request For Information (RFI) and drawing clarification requests, site visits and inspections, equipment start-up, participation in the commissioning process, punch list development, and other activities as required by the contract.

## B. Pressurization Analysis:

A room by room pressurization analysis shall be prepared by the A/E and submitted at the design development phase to demonstrate pressurization relationships of adjacent areas. A schematic room layout shall be prepared and submitted with the pressurization analysis to graphically demonstrate anticipated direction of airflows between areas to be kept under positive pressure and negative pressure differentials in containment spaces. The design documents shall include a room-by-room air balancing schedule to numerically identify supply air quantity, exhaust air quantity and offset.

## C. Contractor's Requirements:

Project construction specifications shall require the contractor to provide the following:

- Contractor shall provide startup, testing and operation verification for all equipment provided in the project.
- Contractor shall provide owner training for all equipment provided in the project. This shall include testing, operation and maintenance. Training shall be video taped for future training sessions. Copy of the DVD shall be turn into the Project Officer.
- Contractor shall provide complete Operation & Maintenance (O&M) manuals for all equipment provided in the project. This shall include copies of all equipment related shop drawings, and copy of all warranties and guarantees with the appropriate contact information. An electronic copy, CD or DVD format, shall also be provided. Scanned copies are not acceptable.

## D. NIH Review of Contractor's Submittals:

NIH reserves the right to review any and all contractors' construction and equipment submittals. At the NIH Project Officer's request, copies of contractors' submittals may be required for NIH's review and concurrence. The A/E shall incorporate any and all NIH review comments in the contractor's submittal.

## E. Renovation Projects:

Renovation projects vary in size and scope. Complexity of renovation projects may also vary depending on the location and the type of functions in the adjacent occupied areas. In order to minimize the impact to research in adjacent spaces, maintain the safety of staff working in adjacent spaces as well as the public in general, avoid unnecessary shutdowns, and avoid contamination of ongoing research and spaces a number of precautions shall be implemented. The A/E shall include, in the construction documents, a proposed construction plan that is to include measures to be implemented by the contractor. In addition, the contractor is to be required to further develop the construction plan and submit it to the Project Officer for review and approval. Some of the construction measures include but are not limited to:

- All lab waste is to be removed and the space decontamination process must be completed prior to any demolition work.
- Dust-proof / fire-rated barriers shall be placed prior to any demolition work. These barriers may include the use of fire-rated plastic sheeting, entry vestibules, and gasketed doors.
- Seal all wall penetrations into the construction area.
- Establish entering and exiting pathways and procedures
- Debris shall be removed in covered carts
- Exterior windows shall be sealed to reduce infiltration

- Air from areas being renovated shall not be re-circulated to the building air-conditioning system.
- Area being renovated shall remain under negative pressure in relation to the surrounding areas.
- Core drilling and vibration producing activities shall be deferred to unoccupied periods
- Use of sticky floor mats.
- Routinely clean up shall include HEPA vacuuming. This may also include routinely floor mopping. This may be required multiple times a day.
- All Laboratory space renovation shall be reviewed by DOHS and the Division of Radiation Safety (DRS)

# Section 6-2: Air-Handling Systems



## 6-2-00 Design Requirements

### A. Air Handling Systems:

NIH facilities shall utilize air-handling systems to provide heating, ventilation, and air-conditioning. Air-handling systems shall be fully automated and shall maintain the space temperature and humidity within the required range. These air-handling systems shall comply with the following:

- Central air-handling units shall utilize 100% outdoor air for continuous, year-round operation. Air recirculation is not permitted within research laboratory and animal facilities.
- All supply air to each laboratory and animal holding/support area shall be controlled by a dedicated, pressure independent air terminal device(s) equipped with hot water reheat coil(s).
- Fan coil units may be used to supplement the cooling capacity where ventilation and make-up requirements are met by the central air-handling system. Fan coil units shall not be located in tissue culture rooms.
- Laboratories that are provided with minimum required outdoor air ventilation and filtration from a central supply air system, supplemental terminal conditioning units shall be permitted to efficiently offset high cooling and heating loads without the use of single pass air from the central system using the guidance in the following references.

Reference;

1. Memarzadeh, “Energy Efficient Laboratory Design: A Novel Approach to Improve Indoor Air Quality and Thermal Comfort”; American Biological Safety Association (ABSA) Journal, Vol. 12, No. 3, 2007

2. Memarzadeh, “Controlling Laboratory IAQ and Energy Costs”; Heating, Piping, and Air-Conditioning Engineering (HPAC), October, 2007

- The use of unitary direct expansion equipment shall be restricted to serve unique areas, such as computer rooms and support facilities, and only when chilled water is not available.
- Capacity and size of the make-up air system to serve fume hoods shall correspond to one 1.2 m (4 ft.) wide vertical sash fume hood in every other laboratory module.
- Capacity and size of the make-up air system for serve containment devices/equipment shall correspond to 120% of the programmed containment devices/equipment.
- Capacity of the cooling system shall include the program cooling demand plus an allowance for 20% future expansion of internal heat gain requirements.
- Minimum space ventilation rates (ACH) shall be as per requirements in Section 6-1.

## A.1 System Redundancy:

Air-handling systems shall be provided with the following:

- Air-handling units (AHU) shall be designed to provide N+1 reliability and maintain 100% capacity in the event of a lead component failure.
- Multiple parallel air-handling units shall be provided to operate simultaneously to meet full load conditions. Each AHU and its related components shall be capable of total isolation by the use of isolation dampers located upstream and downstream of each air-handling unit.
- Upon failure of any major component related to an AHU serving biomedical laboratories (non-containment such as BSL2), the remaining available air-handling equipment shall provide a minimum ventilation rate of 6 ACH in the affected area.
- Upon failure of any major component related to an AHU serving animal housing and support facilities (non-containment such as ABSL2), the remaining available HVAC air-handling equipment shall meet the entire HVAC load in the affected areas.
- Manifolding of AHUs to the same header shall be allowed for units operating at external static pressure differing not more than 0.19 kPa (0.75 in. wg) from each other.
- AHUs serving ABSL facilities shall be completely separate from other air handling systems.

## B. Air distribution Systems

Air distribution system shall deliver heated and cooled air to all spaces to maintain the required space temperature range. Supply air to each individual room shall be balanced for the actual airflow requirements (the highest cooling load or makeup air/ventilation airflow requirement). The central supply and exhaust air systems shall be balanced for the total of the individual airflow requirements in each room plus the allowable duct leak based on the SMACNA duct construction manual. Air temperature and air amount to each space shall automatically adjust as appropriate to accommodate variations in the space heating and cooling loads. The duct system design for NIH buildings shall consider space configuration,

space air diffusion, noise levels, duct leakage, duct heat gains and losses, balancing methods, fire and smoke control, initial investment cost, and system operating cost.

The ductwork systems shall be designed, fabricated and installed in accordance with ASHRAE and SMACNA standards. Refer to Exhibit X6-2-A for a list acceptable air velocities to be used in the design and sizing of different HVAC components:

Ductwork may be single-wall or double-wall construction. It may also be round, flat oval, or rectangular shape. Duct fittings, joint methods, supports, and construction details shall be in accordance with SMACNA standards. All fittings shall have documented pressure loss coefficients by either SMACNA or ASHRAE. Irregular or makeshift fittings are not acceptable. Factory-fabricated fittings by independent manufacturers may be utilized provided they have catalogued performance criteria.

Construction Documents shall specify the ductwork construction material, sealing and leakage class, and pressure classification construction as per SMACNA standards. Refer to exhibit X6-2-B for a table showing the minimum ductwork construction to be used in NIH facilities.

Construction documents shall require the sheet metal contractor conduct pressure tests of the installed ductwork to quantify the leakage rate of the installed systems. Duct leakage tests shall be conducted in accordance with SMACNA standards. Ductwork shall be fabricated and installed to meet the sealing and leakage requirements in the following table:

| Duct Seal and Leakage Classes | | | |
|---|---|---|---|
| | Duct Pressure Classification (Rated Static Pressure) | | |
| | 500 Pa (2 in. wg) and below | 750 Pa (3 in. wg) | 1000 Pa (4 in. wg) and up |
| NIH Required Seal Class | A | A | A |
| NIH Required Sealing | Joints, Seams and All Wall Penetrations | Joints Seams and All Wall Penetrations | Joints Seams and All Wall Penetrations |
| NIH Required Leakage Class (1) - Rectangular Metal | 6 | 6 | 6 |
| NIH Required Leakage Class (1) - Round Metal | 3 | 3 | 3 |

(1) See SMACNA "HVAC Air Duct Leakage Test Manual", 1985 edition, Figure 4-1 for maximum allowable leakage for the each leakage class

Wet exhaust ducts or those duct systems that tend to carry moisture shall be pitched toward the source of moisture generation. Drainage shall be provided in these systems.

Duct lining is not permitted for use in air handling equipment and duct systems. Duct lining is not permitted for either acoustical or insulation purposes; sound attenuators shall be used for controlling noise. In addition, air streams shall not be in contact with any fibrous or porous materials.

Flexible ductwork may be utilized for supply air application to connect diffusers, grilles and registers to low-pressure duct mains. Flexible duct runs shall be limited to 1.8 m (6 ft.). Flexible ducts shall have a UL-rated velocity of at least 20.3 m/s (4,000 fpm) and a maximum UL-rated pressure of 2.5 kPa (10 in. wg) positive. Flexible ducts shall be factory insulated and comply with the latest NFPA Standards 90A and 90B. Flexible duct connections shall be made using stainless steel draw bands and manufacturer-approved tape. Flexible ductwork shall not be used for laboratory exhaust.

All ductwork penetrating room wall (Above the ceiling) and all diffuser/register/grille penetrating hard ceilings shall be sealed. See Exhibit X4-2-A "Joint Sealant and Caulking" table.

## C. Location of Outdoor Air Intakes and Exhaust Air Discharge:

Outdoor air intakes and exhaust discharges shall be located away from each other and to avoid re-entry of exhaust contaminants from any source. Exhaust contaminants may be from any of the following sources: all type of exhaust fans including animal room exhaust and lab exhaust, air-handling unit relief air, vehicle exhaust, loading docks, automobiles entrances, drive ways, passenger drop-offs, cooling towers, boiler or incinerator stacks, emergency generators exhaust, vacuum pumps exhaust, steam relief vents or other hot vents, plumbing vents, vents from steam condensate pumps units, kitchen hoods, refrigerant relief vents, mechanical/electrical room ventilation systems, etc.

Outdoor air intakes shall be, at least, 12 m (40 ft.) away from any of the exhaust contaminants sources listed above regardless of discharging upward, horizontally or deflected downward. Other factors such as wind direction, wind velocity, stack effect, system size, height of building(s), and security concerns shall be evaluated, and location of intakes and outlets adjusted accordantly.

The bottom of all outdoor air intakes shall be located as high as practical, but not less than 3.6 m (12 ft.) above ground level and/or any adjacent building or site element within a horizontal distance of 4 m (13 ft.) from the air intake.

Construction documents shall include the design of exhaust stack height and discharge air velocity characteristics to overcome the building cavity boundary and avoid re-entrainment of exhaust. Stacks shall be shown as part of the architectural design and the design rationale shall be described in the early design reports. In general, exhaust stacks shall be designed to meet the following requirements:

- Discharge shall be a minimum of 3 m (10 ft.) above the roofline and any roof element within a horizontal distance of a 4 m (13 ft.) radius
- Upward velocity shall be a minimum of 15 m/s (3,000 fpm) at the point of discharge. Reentry calculations may dictate higher discharge velocities.
- Safety concerns shall always take precedence over aesthetics.
- Manifolds for multiple exhaust fans shall have separate exhaust stacks for each fan to avoid having positive pressure ductwork on the discharge side of fans not operating.

See Appendix E.2 "Calculating Minimum Separation Distance Between Intakes And Exhausts" for a computational analysis in evaluating building external air flows as influenced by new and existing obstacles.

## D. Air-Handling Units:

The Basis of Design report shall define the type and quality of air-handling equipment proposed for use in NIH facilities. In addition, the report shall provide justification for the equipment selection. The following requirements apply to all air-handling units to be used in NIH facilities:

- Casings shall be double wall construction for all sections of the entire air-handling unit. Wall construction shall be a minimum of 50 mm (2 in.) thick insulated panel with 48 kg/m$^3$ (3 lb/ft$^3$) density insulation in accordance with ASTM E84. Exterior panel shall be 1.316 mm (18 gauge) solid G90 galvanized steel. All interior panels shall be 1.621 mm (16 gauge) solid G90 galvanized steel. Interior panel shall be the panel that withstands the unit's internal air pressure. Unit floor shall be a minimum of 4.7 mm (3/16 in.) aluminum plate with diamond tread, all welded construction. Panel construction shall allow the replacement of individual panel sections without disturbing adjacent panels. Outdoor units shall be a minimum of 80 mm (3 in.) thick panels. Outdoor units shall have the exterior panels painted with a minimum of a three step paint process to pass a 1000 hour salt spray per ASTM B-117.
- Casing construction shall include thermal breaks between exterior panels and interior panels.
- Casing construction shall be water and air tight. The manufacturer's standard cabinet construction shall comply with the latest ASHRAE/ANSI Standard 111 leakage class of less than 9 for demount units as measured in accordance with AMCA Standard Z10-

85. The fully assembled unit shall have a maximum air leakage rate of 1% of the supply air volume.

- All factory and field penetrations shall be completely seal and not reduce the leakage rating of the casing. This includes all casing penetrations within the unit and between unit's components. All penetrations for components such as electrical lighting, controls, etc. shall be sleeved and caulked to prevent leakage and condensation damage. This shall also apply to heat recovery units.
- Access doors shall be provided on both sides of each equipment section. Doors shall be a minimum of 600 mm (24 in.) wide. Each door shall be provided with a vision panel no less than 300 mm (12 in.) by 300 mm (12 in.). Door swing shall help seal the access door with the unit's internal air pressure.
- Lights shall be waterproof, marine type, and provided in all sections of the unit, which are more than 1.4 m (54 in.) high. Lights shall be controlled from a single pilot switch located adjacent to one of the access doors.
- Air filters may consist of cartridge-type elements; roll filters are not acceptable. The design face velocity shall not exceed 2.5 m/s (500 fpm) nor shall manufacturers' standard nominal ratings be exceeded. The preferred filter face section dimensions are 600 mm (24 in.) x 600 mm (24 in.). Pre-filters shall be utilized. All filter banks shall have intermediate supports to prevent bank deflection at maximum design pressure differentials. Minimum 30% efficient filters shall be installed upstream of any heat recovery device.
- A pressure gauge shall be provided, on the unit's exterior, at each filter section. One gauge shall be provided for each filter bank.
- Coils shall have copper tubes with aluminum fins. Galvanized coil frame shall be provided for heating coils and stainless steel frame for cooling coils. The use of Turbulators is not acceptable.
- Cooling coil's air face velocity shall sized for a nominal air face velocity not to exceed 2.0 m/s (400 fpm) for the present design conditions and 2.5 m/s (480 fpm) for the future growth capacity.
- Maximum size for individual coils shall be 3.0 m (10 ft.) long by 0.91 m (3 ft.) high. If larger coils are required then multiple coils shall be provided.
- Multiple coils shall be valved separately so that, if any individual coil fails, it can be isolated and drained while the remaining coils stay in operation. Coils shall be installed to allow the removal of individual coils without disturbing pipe headers or anything else that would prevent the remaining coils from operating. Coils shall be removable without major rigging.
- Integral face by-pass dampers/coils are preferred over standard coils with separate bypass dampers.
- Return header for multiple-stacked coils shall be piped in a reverse return configuration to assist with the balancing of the water flow. Strainers shall be provided on the

feed line for each coil bank. Control and balancing valves shall be installed on the return line. Each coil shall be provided with a balancing valve with integral memory stop. Combination balancing, shutoff, and flow meter devices are not acceptable.

- Each AHU section shall be provided with drains that permit the internal wash down of the unit in the event of a coil failure.
- Drain pans shall be provided for each cooling coil. Intermediate stainless steel drain pans shall be provided for each coil bank, which is more than one coil high. Drain pans shall extend a minimum of 12-in downstream of the cooling coils. The drain pan shall be stainless steel with a positive slope to a bottom drain connection. Pan drains shall be properly trapped. Static pressure conditions accounting for dirty filter(s) shall be used to calculate the trap height.
- Moisture eliminators may be considered where carryover presents a problem. However, eliminators shall not impede service access for cleaning of the coil face surface.
- Fans may be vane-axial, airfoil centrifugal (single or double width), or plenum as justified by life-cycle cost analysis. All fans shall be of a minimum construction class II as per the Air Movement and Control Association (AMCA). Fans shall be totally isolated from the unit by the use of inertia bases and spring isolation. Fan volume control shall be achieved by using controllable pitch vanes on axial fans and VFDs on centrifugal and plenum fans. Fans shall be arranged in the draw-through position. Blow-through configurations are not allowed.
- Fans shall be vibration isolated from the remaining parts of the unit and the connecting ductwork system.
- Fan shafts shall be solid
- When space limitations dictate that fans be placed in close proximity of heating or cooling coils, the distance between the fan inlet and the coil shall be a minimum of a wheel diameter for single width fans and 1.5 wheel diameter for double width fans
- Sound attenuators may be necessary to meet the room sound criteria. When feasible, they shall be integrated as a part of the AHU. Sound attenuators shall be pack-less type. The silencer rating shall be certified in accordance with ASTM E-477.
- Control dampers shall be low leakage opposite blade for modulation control and parallel blade for open-closed operation. Ultra-low leakage, industrial-quality isolation dampers shall be installed at the discharge of manifolded systems.
- Unit louvers shall be AMCA rated and selected for low-pressure drop with less than 0.003 kg/m$^2$ (0.001 lb/ft$^2$) penetration at 3.8 m/s (750 fpm) free-area velocity.
- Heat recovery may be considered as demonstrate by the life cycle analysis. The heating and cooling coils shall be designed to function at full load with or without the energy recovery system. Units with heat recovery systems shall be designed such that devices could be out of commission without any interruption to AHU system operation.

## D.1 Air-Handling Units Type:

Air-handling unit's type and configuration would depend on the unit size and the particular type of project:

- Factory-package air-handling units are generally small in capacity, less than 9,440 L/s (20,000 cfm), and do not serve critical program functions.
- Factory-fabricated, custom-designed, central AHUs are generally large, greater than 9,440 L/s (20,000 cfm) that use 100% outdoor air.
- Field erected, custom designed, central AHUs are generally large and are designed for installation in existing buildings where access is restricted, or designed for new buildings where the construction phasing does not permit the installation of large factory-fabricated sections.

## D.1.a Factory-Package Air-Handling Units:

Factory-packaged air-handling units shall comply with the additional following requirements:

- All units shall be institutional-grade.
- All unit sections shall have full-height access doors to permit inspection and service of all components
- External fan motors are preferred, and in all cases, fan bearing lubrication piping shall be extended to the exterior to the casing wall.
- Units shall be in a draw-through arrangement.
- Factory-packaged units shall have offset coil pipe headers to allow individual coils to slide out of unit casings.
- Units shall be fully tested at the factory before shipping. Testing shall verify capacity and leakage rate. Unit casings shall be pressure rated for the total system design operating pressure plus 25%.

## D.1.b Factory –Fabricated Air-Handling Units:

Factory-fabricated air-handling units shall be fabricated as per details in the contract documents. Contract documents shall fully detail the size, dimensions, and specific component configuration of each factory-fabricated air-handling unit, including: all components, capacity of all components, all controls components, all sequences of operation, access areas, access doors, casing openings, service clearances, and overall dimensions. Layouts shall include sections to define the overall height and vertical location of duct connections, dampers, louvers, etc. These units shall comply with the additional following requirements:

- All units shall be custom-designed and of institutional grade.
- Units shall be preassembled fully tested at the factory before shipping. Testing shall verify capacity and leakage rate. Unit casings shall be pressure rated for the total sys-

tem design operating pressure plus 25%. After installation at the field, these units shall be field-tested.

- Units shall be preassembled on a structural steel base. The units shall be shipped as one piece if possible, or in as few sections as possible. The number of field-casing joints shall be reduced as much as feasible.
- Casing shall be double wall and factory fabricated with structural, acoustical, and thermal performance certified by testing data. Casings shall have a solid interior and exterior shell and true thermal breaks.
- Casing access doors are required on both sides of each unit component including: heating and cooling coils, fans, filters, dampers, sound attenuators, heat recovery devices, humidifiers, and any other components requiring routine service. Access doors shall be man sized, 0.6 m (2 ft.) wide x 1.8 m (6 ft.) high

### D.1.c Field Erected Air-handling Units:

Field erected units shall be fabricated as per details in the contract documents. Contract documents shall fully detail the size, dimensions, and specific component configuration of each field erected air-handling unit, including: all components, capacity of all components, all controls components and all sequences of operation, access areas, access doors, casing openings, service clearances, and overall dimensions. Layouts shall include sections to define the overall height and vertical location of duct connections, dampers, louvers, etc. These units shall comply with the additional following requirements:

- All units shall be custom-designed and of institutional grade.
- Unit casing shall be pressure rated for the total system design operating pressure plus 25%. After the field installation is complete, these units shall be field-tested as a complete unit to verify capacity and leakage rate
- Casings shall be double wall and factory fabricated with structural, acoustical, and thermal performance certified by testing data. Casings shall have a solid interior and exterior shell and true thermal breaks.
- Casing access doors are required on both sides of each unit component including: heating and cooling coils, fans, filters, dampers, sound attenuators, heat recovery devices, humidifiers, and any other components requiring routine service. Access doors shall be man sized, 0.6 m (2 ft.) wide x 1.8 m (6 ft.) high
- Contractor-shop-fabricated casings or filter frames for air-handling units are prohibited.
- These units shall be fully field tested.

## E. Air Filtration Systems:

Air Filtration shall be provided to all supply air used to provide heating and air-conditioning. As a minimum, supply air shall pass through a pre-filter and filter on the upstream side of heating and cooling coils. Filter average efficiencies shall be MERV-8 (30%) and MERV-14

(95%) respectively, based on ASHRAE Standard 52.2, Minimum Efficiency Reporting Value (MERV). HVAC air systems shall automatically adjust fan speed to compensate for the additional system static pressure produced by filter loading. In addition, the following shall be provided:

- Final filtration shall be provided downstream of supply air fans serving ABSL facilities to protect against particulate and other containments possibly generated by the air handling equipment. Average efficiency of the final filters shall be MERV-14 (95%), based on ASHRAE Standard 52.2, Minimum Efficiency Reporting Value• The A/E shall review the project's program requirements to establish specific filtration criteria.

## F. Humidification Systems:

Winter humidification shall be provided where required to maintain space humidity requirements. In the Bethesda campus steam from the central plant shall be utilized for this purpose. In other NIH locations, the A/E shall verify suitability of using plant steam with the Project Officer during the design stage. Written record of this verification shall be included in the Basis of Design Report.

Humidification systems shall comply with the following:

- Clean steam shall be used for humidification in special areas such as: transgenic animal housing and barrier housing. Clean steam shall also be used for autoclaves, sterilizers, and rack washers when required by program and/or manufacturer.
- The A/E shall consult with the Project Officer to establish a list of additional areas requiring the use of clean steam.
- Clean steam shall be produced by a steam-to-steam generator by vaporizing either: RO water, double distilled water or softened water.

Humidifiers shall be steam separator type with jacketed steam injection, which do not require a drain from the steam manifold. They may be located within air-handling units or installed in the supply air ductwork. Duct mounted steam distribution manifold shall be installed within a fully welded stainless steel ductwork section. The stainless steel section shall extend 0.6 m (2 ft.) upstream the manifold and at least 2 m (6 ft.) downstream the manifold. The down stream length may need to be extended depending on the absorption distance for the particular system design. Stainless steel ductwork shall be pitch and connected to a drain. Steam piping to the humidifier shall include a manual isolation valve for equipment isolation during service. Humidifier controls shall include an automatic isolation valve to remain close during cooling mode. Humidifier controls shall also include a high limit humidistat located downstream of the humidifier manifold.

## G. Fans:

Variable and constant air volume centrifugal and plenum fans serving multiple zones shall be equipped with variable frequency drives (VFDs) for control of volumetric flow rate and duct static pressure.

All fans on a manifold or in parallel configuration shall be identical and have identical isolation dampers and volume/pressure controls.

All fans shall be constructed to meet a Class II rating. They shall be fully accessible for inspection, service and routine maintenance. Fan bearings, where possible, shall be serviceable from outside hazardous or contaminated exhaust airstreams. Inline fans with motors or drive exposed to exhaust airstreams are not permitted.

Fans shall have a certified sound and air rating based on tests performed in accordance with AMCA Bulletins 210, 211A, and 300. See AMCA Standard 99, Standard Handbook, for definitions of fan terminology. The arrangement, size, class, and capacity of all fans shall be scheduled on the contract drawings.

Certified fan curves including power curves as well as acoustical data shall be submitted for each fan. All data shall be from factory test(s) performed in accordance with applicable AMCA standards. Data shall include published sound power levels based on actual factory tests on the fan sizes being furnished and shall define sound power levels (PWL) (10-12 W for each of the eight frequency bands).

Fan curves shall show: volumetric flow rate of the fan as a function of total pressure, brake horsepower and fan efficiency. System curves shall include estimated losses for field installation conditions, system effect, and actual installed drive components. All losses shall be defined on the fan curves. Data may also be submitted in tabular form, but tables are not a substitute for actual performance curves.

All fans shall be statically and dynamically balanced by the manufacturer and shall be provided with vibration isolation. All fans 18.6 kW (25 HP) and larger shall also be dynamically balanced in the field by the manufacturer upon installation completion. All fan's parts shall be protected against corrosion prior to operation.

Belt driven fans shall be provided with drives with multiple V-belts. Belts shall be cogged type and shall be constructed of endless reinforced cords of long staple cotton, nylon, rayon, or other suitable textile fibers imbedded in rubber.

Variable-pitch sheaves shall be used to accommodate initial balancing and shall be replaced with fixed pitch when balancing is complete. Sheaves shall be constructed of cast iron or steel, bored to fit properly on the shafts, and secured with keyways of proper size (no setscrews) except that for sheaves having 13 mm (1/2 in.) or smaller, bores setscrews may be used.

Fans shall be furnished complete as a package with electric motors, motor drives, fan bases, and inlet and outlet ductwork connections.

## H. Motor and Variable Frequency Drives:

Refer to section 10 “Electrical” for additional requirements

### H.1 Motors:

Motors utilized on NIH projects shall be premium high efficiency and selected to optimize the efficiency of mechanical and building systems. Motors shall always be of adequate size to drive the equipment without exceeding the nameplate rating at the specified speed or at the load that may be delivered by the drive.

Motors shall be rated for continuous duty at 115% of rated capacity and base temperature rise on an ambient temperature of 40°C (105°F). Motors 560 W (3/4 HP) and larger shall be three-phase, Class B, general-purpose, squirrel cage, open-type, premium-efficiency induction motors in accordance with National Electrical Manufacturers Association (NEMA) Design B standards, wound for voltage specific to the project, 60 Hz AC, unless otherwise required by the design. Motors 373 W (1/2 HP) shall be either single or three-phase. Motors smaller than 373 W (1/2 HP) shall be single-phase, open-capacitor type in accordance with NEMA standards for 115 V, 60 Hz, AC. Motors 124 W (1/6 HP) and smaller may be the split-phase type.

All motors 0.75 kW (1 HP) and larger shall have a composite power factor rating of 90% to 100% when the driven equipment is operating at the design duty. Devices such as capacitors, or equipment such as solid-state power factor controllers, shall be provided as part of the motor or motor-driven equipment when required for power factor correction.

Motors specified to be controlled by variable speed drives shall be rated for such use. Per CEE Premium Efficiency Criteria, minimum efficiencies for TEFC motors shall be equal or greater than those shown in the minimum efficiency table included in Exhibit X6-2-C “Minimum Motor Efficiency”.

## H.2 Variable Frequency Drives:

Variable Frequency Drives (VFD) to be used in NIH facilities shall include consideration to the following:

- Harmonic distortion on both the supply and motor side of the VFD.
- Equipment de-rating due to harmonic distortion produced by VFDs.
- Audible noise caused by high-frequency (several kHz) components in the current and voltage.

The design of system utilizing VFDs shall incorporate the following provisions:

- An independent and dedicated VFD shall be provided for each prime motor and each standby motor in equipment requiring the use of VFDs.
- Equipment motors shall be matched to the drive so that low speeds can be achieved.
- VFDs shall have a manual bypass independent of the drive. For motor 37.3 kW (50HP) and larger, a reduced voltage starter shall be provided in the by- pass circuit. Motors shall operate at full speed while in the bypass position whenever the speed drive is de-energized and/or open for service.
- VFDs shall be located in environments that are within manufacturer's specifications.
- VFDs that serve fans shall be able to maintain operation during short power fluctuations. That is the VFD shall be able to maintain the operation of the motor during short interruptions of the building electrical power system with out the need to shutdown the equipment and without damaging the motor.
- 18 pulse VFDs shall be provided for all motors 56 kW (75 HP) and above.
- 6 or 12 pulse VFDs shall be provided for all motors less than 56 kW (75 HP).
- VFDs shall be provided with integral passive or active harmonic filters, phase multiplication devices and any other components required to mitigate harmonic voltage total distortion (THD) to 5%, current THD to 5% at any load level, and no individual harmonic greater than 3% distortion.
- Compliance measurement shall be based on actual THD measurement at the VFD circuit breaker terminals during full load VFD operation. Designs which employ shunt tuned filters shall be designed to prevent the importation of outside harmonics, which could cause system resonance or filter failure. Calculations supporting the design, including a system harmonic flow analysis, shall be provided as part of the submittal process for shunt tuned filters. Any filter designs, which cause voltage rise at the VFD terminals, shall include documentation in compliance with the total system voltage variation of plus or minus 10%. Documentation of Power Quality compliance shall be part of the commissioning required by the VFD supplier.
- Actual job site measurement testing shall be conducted at full load condition and a copy of the report shall be included in the operation and maintenance manuals. Har-

monic measuring equipment utilized for certification shall carry a current calibration certificate. The final test report shall be reviewed for compliance by a manufacturer's certified representative. Text and graphical data shall be supplied showing voltage and current waveforms, THD and individual harmonic spectrum analysis in compliance with the above standards.

- VFD locations shall be as close as practical to motor to minimize motor circuit conductor length issues. VFD incoming power wiring, wiring from VFD to motor, and motor control wiring shall be installed in separate, dedicated conduits.

Refer to Appendix E.4 "Harmonic Control in Electric Power Systems" for additional information regarding harmonic distortion concerns. Refer to Appendix E.6 "Selecting and Specify Variable Frequency Drives for HVAC Systems" for additional information regarding variable frequency drives concerns.

## I. Emergency Electrical Power Generators:

Emergency electrical power generators shall comply with the following requirements:

- Generator set shall be located in such way to facilitate service and future replacement.
- Provide at least 1.2 m (4 ft.) of clearance space around the generator set. There shall be access for replacing the engine and/or the electric generator without moving the generator set or accessories, such as the day tank.
- Generator set shall be installed to avoid producing structure-borne vibration.
- Generator set shall be located where it will be acceptable to have the noise generated from engine, radiator fan, and exhaust system.
- Generator set shall be located away from areas of high ambient temperatures.
- Generator set shall be located to provide protection from the weather and from vandalism.
- Location of the engine exhaust discharge shall be determined by a wind wave analysis.
- See Chapter 10, Electrical, for additional requirements.

Engine exhaust system shall not create excessive back pressure on the engine and shall not be connected to any other exhaust system serving other equipment. Soot, corrosive condensate, and high exhaust-gas temperatures will damage idle equipment served by a common exhaust system.

Engine exhaust piping shall comply with the following:

- Refer to Exhibit X6-3-A for requirements of the engine exhaust pipes:
- Exhaust pipes shall be freestanding, not supported by the engine or muffler.
- Exhaust pipes shall use vibration-proof flexible connector.

- Exhaust pipes shall be guarded to prevent contact with personnel, and avoid personnel injuries and burns.
- Exhaust pipes shall be routed to avoid fire detection devices and automatic sprinkler heads.
- Exhaust pipes shall be vented to the atmosphere away from building doors, windows, and ventilation intake vents. Insulated thimble pipe fittings shall be used at the point where the exhaust pipe penetrates the exterior wall or roof. A hinged rain cap shall be provided on the vertical discharge.
- Horizontal exhaust pipes shall be pitched downward and away from the generator set. At the end of the horizontal run, a condensate drain trap with hose connection shall be provided. A drain valve shall be provided at the bottom of each vertical section of the exhaust piping.

Sound reducing mufflers shall be included in the engine exhaust system muffler. It shall be either inside or outside the generator set enclosure. Construction documents shall include the selection of the proper muffler to reduce the exhaust noise to an acceptable level.

- Residential Muffler: suitable where some low background noise is always present, 18 to 25 dB (A) sound reduction.
- Critical Muffler: suitable for hospitals, residential dwellings or where background noise is minimal, 25 to 35 dB (A) sound reduction.
- The muffler shall be installed as close as possible to the engine.

Generator sets that are installed outside a building, with integral weather protective housing, shall have critical-grade type mufflers. The generator set shall be located so engine exhaust will disperse away from buildings, building air intakes, and will not cover walls and windows with soot.

## I.1 Emergency Generator Room Ventilation:

The space where the emergency generator is located shall include a ventilation system to remove heat and fumes dissipated by the engine, electrical generator, accessories, and other equipment located in the room. A maximum 11°C (20°F) room temperature rise above ambient shall be utilized in designing the ventilation air system.

Air intake louvers to ventilate the generator room shall be sized to accommodate the amount of combustion air needed by the engine, the amount of cooling air that flows to the radiator and any other amount of air needed to ventilate the room. Control air dampers on the air intake louver shall be fast acting to meet code requirements.

## I.2 Engine's fuel oil system:

The emergency generator shall be provided with a safe an uninterrupted source of fuel oil #2. The fuel oil system shall be engineered and installed to industry standards. The design of the fuel supply and storage system shall comply with the following requirements:

- The fuel oil supply tank shall be located as close as possible to the emergency generators. Emergency generator(s) fuel oil shall not be used for any other purpose and shall not be shared with any other equipment.
- The fuel oil supply tank shall hold enough fuel oil to run the generator(s) at full load for a minimum of 24 hours without refueling. Tank-sizing calculations shall be based on the full load hourly fuel consumption. Other considerations for tank sizing shall include the duration of expected power outages versus the availability of fuel deliveries and the shelf life of the fuel oil. The shelf life of #2 fuel oil is 1.5 to 2 years.
- The design of the fuel oil system shall specify all tank specialties such as fuel level alarms, filling accessories, control devices and all monitoring and testing devices.
- Underground fuel oil supply tanks shall be double wall fiberglass and shall be provided with a leak detection and monitoring system.
- Day tanks shall be as close as practical to the generator's engine and shall be at an elevation where the highest fuel level in the day tank is lower than the diesel fuel injectors. Day tanks shall be vented to the outside when installed indoors.
- Underground fuel oil piping shall be double wall fiberglass and shall be provided with a leak detection and monitoring system. Above ground fuel oil lines shall be black steel. Compatible metal fuel oil pipes and fittings shall be used to avoid electrolysis.
- A flexible section, of code-approved tubing, shall be used between the engine and the fuel supply line to isolate vibration from the generator's engine.
- Fuel oil supply pipes and pumps shall be sized to handle a fuel oil flow rate three times greater than the full-load fuel oil consumption rate specified by the generator manufacturer. In multiple day tanks applications, the main fuel oil pump system shall be sized for three times the total fuel oil flow with all generators at full load simultaneously. Fuel oil return pipes may be sized for twice the total fuel oil flow. Engine return-fuel oil shall be piped to the fuel oil supply tank.
- The fuel oil supply line to each generator shall be provided with an electric solenoid shutoff valve. The solenoid valve shall be connected to the engine starter circuit to open the valve prior to energizing the generator.

## I.3 Equipment connected to the Emergency Electrical Power System:

Emergency electrical power shall be provided to all critical mechanical and laboratory equipment. At a minimum the following mechanical equipment shall be connected to the emergency electrical power system.

- Exhaust air fans. This includes: all lab exhaust, all animal room exhaust, all fume hoods exhaust, and critical exhaust air systems
- Supply air fans, exhaust air fans, and all associated devices and equipment which serve animal room environments.
- Supply air fans associated with exhaust fans, which are connected to the emergency power. These supply air fans shall provide a comparable amount of supply air to maintain pressure differential between rooms, air to serve fume hoods, and to prevent cross contamination and the building from becoming negative.
- Air handling systems associated with the active smoke purge/evacuation systems.
- Computer room air handling units.
- Air-conditioning system serving the main telecommunications room.
- Air-handling system serving elevator machine rooms, when elevators are on emergency power.
- Water chillers, cooling towers, pumps, and associated systems, which serve critical areas.
- Heating systems including: boilers, heating water pumps and associated fuel oil system.
- Steam condensate pumps.
- Pumps and all devices and components associated with the fuel oil system serving the emergency electrical power generator.
- Entire automatic temperature control system including: control panels, control devices, air compressors, etc.
- Electrical heat tracing for hydronic piping.
- Domestic water pumps.
- Sewage ejector pumps.
- Sump pumps.
- Medical gas systems including: compressors, pumps, controls and associated alarms.
- Hands free toilet flushers and lavatory faucets.
- Critical scientific equipment identified by program requirements.

## 6-2-10 Design Guidance (Reserved)

## 6-2-20 Design Information (Reserved)

# 6-2-30 Design Document Requirements

## A. Testing and Balancing:

The design of HVAC systems for NIH buildings shall include a complete and comprehensive testing, adjusting, and balancing of environmental and mechanical systems to produce the design objectives. The testing and balancing shall be done in coordination with the commissioning process as required by the NIH Model Commissioning Guide.

The testing and balancing (TAB) process shall be specified to meet one or both of the following standards (latest edition):

- National Standards for Total System Balance as defined by the Associated Air Balance Council (AABC)
- Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems as published by the National Environmental Balancing Bureau (NEBB)

All TAB work shall be performed by an independent TAB contractor who is certified by either AABC or NEBB.

The TAB report shall be certified for accuracy by an independent professional engineer familiar with the testing and balancing of the project but not affiliated with the TAB contractor's organization. The TAB contractor shall provide all required pre-construction plan checks and reviews; shall test, adjust, and balance the air and water system; and shall submit completed reports, floor plans indicating TAB points, analysis, and verification data showing proper system performance that meets the intent of design.

NIH buildings often are constructed and occupied in multiple phases. The TAB process specified shall address the requirements of interim balancing to support occupancy of buildings during completion of multiple construction phases.

The A/E, Project Officer, DOHS, commissioning agent, and research staff shall develop an occupancy/move plan and operation strategy that shall be specified in the contract documents. The A/E shall define a TAB procedures/specifications that fully supports the phasing of the mechanical work, where phasing is required, and assures that the installed mechanical systems adhere to the design objectives during all phases of construction and upon completion of entire project.

| Typical Design air Velocity in HVAC systems | |
|---|---|
| Element / System | Maximum Face Velocity m/s (fpm) |
| Ductwork | |
| - Up to 500 Pa (2 in. wg) pressure class in mechanical shafts<br>- Ductwork above occupied areas<br>- Air outlets devices | 7.6 (1,500)<br>6.1 (1,200)<br>3.8 (750) |
| - 750 Pa (3 in. wg) to 1,000 Pa (4 in. wg) pressure class in mechanical shafts<br>- Ductwork above occupied areas | 12.7 (2,500)<br>10.2 (2,000) |
| - Outdoor/relief air | 7.6 (1,500) |
| - Animal research facility exhaust ductwork | 7.6 (1,500) |
| Coils | |
| - Cooling/dehumidifying coils | 2.3 (450) |
| - Heating Coils - Hot water | 2.5 (500) - 3.8 (750) |
| Filters | |
| - Viscous impingement | 1.0 (200) - 4.0 (800) |
| - Dry-type, extended-surface & Flat (low efficiency) | Duct velocity |
| - Pleated media | 2.5 (500) |
| - HEPA | 1.3 (250) |
| Louvers | |
| - Intake (1)<br>- Exhaust | 2.5 (500)<br>3.8 (750) |

*(1) Air Intake louvers shall be sized to not exceed the rating of the louver and avoid water penetration*

| Minimum Duct Construction Standards | | |
|---|---|---|
| Application | SMACNA Pressure Class (Note 1) Pa (in. wg) | Ductwork Materials |
| All ductwork, unless noted otherwise | 500 (2) | G90 galv. |
| Outdoor air intake, relief, return, and general exhaust air plenums (notes 2, 9, and 10) | 500 (2) | G90 galv. |
| Low-pressure supply air and return air ductwork, constant volume (note 9, and 10) | 500 (2) | G90 galv. |
| Low-pressure supply air ductwork downstream of air terminal units (note 4, 9, and 10) | 500 (2) | G90 galv. |
| Low-pressure return air ductwork upstream of air terminal units (note 4, 9, and 10) | 500 (2) | G90 galv. |
| Low-pressure general exhaust air ductwork (note 9, and 10) | 500 (2) | G90 galv. |
| Low-pressure wet exhaust air ductwork | 500 (11) | Alum or ss |
| Low-pressure hazardous exhaust air ductwork upstream of air terminal units (note 7) | 500 (2) | (note 6) |
| Medium-pressure supply air ductwork upstream of air terminal units, vav or cv air terminal units (note 3) | 1000 (4) | G90 galv. |
| Medium-pressure general exhaust air ductwork downstream of air terminal units, vav or cv air terminal units (note 3) | 1000 (4) | G90 galv. |
| Medium-pressure hazardous exhaust air ductwork downstream of air terminal units, vav or cv, duct operating pressure up to 750 Pa (3 in. wg) (note 3 & 7) | 1000 (4) | (note 6) |
| High pressure hazardous exhaust air ductwork downstream of air terminal units, vav or cv air terminal units, duct operating pressure above 750 Pa (3 in. wg) to 1250 Pa (5 in. wg) operating pressures (note 5 and 7) | Class I/industrial 1500 (6) | (note 6) |
| Hazardous exhaust air, positive pressure segment up to 1250 Pa (5 in. wg) operating pressure (note 7) | Class I/industrial 1500 (6) | (note 6) |
| Special hazard exhaust air ductwork (note 3 and 8) | 1000 (4) | ss |

*Notes:*

*(1) This is the minimum SMACNA pressure classification to be used for the construction of ductwork and associated components in the listed application. Duct construction shall be as listed but no less than 250kPa (1 in. wg) higher than the calculated operating static pressure, including future capacity, for the given section of ductwork, which ever is greater.*

*(2) Plenums need to be constructed of minimum 1.316 mm (18-gauge) G90 galv. steel. These panels need to be insulated*

*(3) Air risers serving multiple floors need to be constructed to meet at least SMACNA 1500 Pa (6 in. wg) duct construction*

*(4) This type of ductwork construction requires compliance with SMACNA class A for duct sealing and leakage.*

*(5) Air risers serving multiple floors need to be constructed to meet at least SMACNA 2500 Pa (10 in. wg) duct construction*

*(6) Epoxy-coated, G90 galvanized steel, or stainless steel (ss)*

*(7) The term "hazard exhaust" generally applies to common exhaust systems serving non-containment laboratories such BSL-2 and ABSL-2, fume hoods, animal research facilities, biosafety cabinets, etc., which, by their relatively light hazard rating, may be exhausted by a common exhaust system serving non-containment areas.*

*(8) The term "special hazard exhaust" generally applies to exhaust air systems serving containment areas such as BSL3 laboratories, radioactive hoods, etc., which, by their critical nature or extreme hazard, shall be exhausted individually and typically require special filtration. Ductwork serving containment areas such as BSL-3 shall be welded stainless steel.*

*(9) Ductwork leak testing for this application is not required.*

*(10) This particular ductwork system does not require leak test during construction.*

*(11) Wet exhaust air ductwork serving sterilizers, autoclaves, and cage washers shall be stainless steel.*

| Minimum Full-Load Nominal Efficiency Of Electric Motors (1) | | | | | | |
|---|---|---|---|---|---|---|
| kW (HP) | Open Motors | | | Enclosed Motors | | |
| | 2 POLE 377 rad/s (3600 RPM) | 4 POLE 188 rad/s (1800 RPM) | 6 POLE 125 rad/s (1200 RPM) | 2 POLE 377 rad/s (3600 RPM) | 4 POLE 188 rad/s (1800 RPM) | 6 POLE 125 rad/s (1200 RPM) |
| 0.75 (1) | 77.0 | 85.5 | 82.5 | 77.0 | 85.5 | 82.5 |
| 1.1 (1.5) | 84.0 | 86.5 | 86.5 | 84.0 | 86.5 | 87.5 |
| 1.5 (2) | 85.5 | 86.5 | 87.5 | 85.5 | 86.5 | 88.5 |
| 2.2 (3) | 85.5 | 89.5 | 88.5 | 86.5 | 89.5 | 89.5 |
| 3.7 (5) | 86.5 | 89.5 | 89.5 | 88.5 | 89.5 | 89.5 |
| 5.6 (7.5) | 88.5 | 91.0 | 90.2 | 89.5 | 91.7 | 91.0 |
| 7.5 (10) | 89.5 | 91.7 | 91.7 | 90.2 | 91.7 | 91.0 |
| 11.2 (15) | 90.2 | 93.0 | 91.7 | 91.0 | 92.4 | 91.7 |
| 14.9 (20) | 91.0 | 93.0 | 92.4 | 91.0 | 93.0 | 91.7 |
| 18.6 (25) | 91.7 | 93.6 | 93.0 | 91.7 | 93.6 | 93.0 |
| 22.4 (30) | 91.7 | 94.1 | 93.6 | 91.7 | 93.6 | 93.0 |
| 29.8 (40) | 92.4 | 94.1 | 94.1 | 92.4 | 94.1 | 94.1 |
| 37.3 (50) | 93.0 | 94.5 | 94.1 | 93.0 | 94.5 | 94.1 |
| 44.7 (60) | 93.6 | 95.0 | 94.5 | 93.6 | 95.0 | 94.5 |
| 55.9 (75) | 93.6 | 95.0 | 94.5 | 93.6 | 95.4 | 94.5 |
| 74.6 (100) | 93.6 | 95.4 | 95.0 | 94.1 | 95.4 | 95.0 |
| 93.2 (125) | 94.1 | 95.4 | 95.0 | 95.0 | 95.4 | 95.0 |
| 111.9 (150) | 94.1 | 95.8 | 95.4 | 95.0 | 95.8 | 95.8 |
| 149.2 (200) | 95.0 | 95.8 | 95.4 | 95.4 | 96.2 | 95.8 |

*(1) As per efficiency values in the NEMA MG 1-1998, table 12-12 for NEMA Premium Efficiency Electric motors*

# Section 6-3: Piping Systems

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## 6-3-00 Design Requirements

### A. Hydronic systems:

Hydronic systems in NIH facilities shall be designed for the ease of system maintenance, component replacement, system reliability, and extended service life. Piping systems shall include the following:

- Piping systems consisting of different hydronic zones shall be provided with interconnecting means to be used when serving critical areas.
- Each piece of equipment shall be provided with means to determine water flow, balance water flow, and control water flow.
- System shall be analyzed to determine if a reverse return piping arrangement would be beneficial to the project.
- Provided a balancing valve and flow meter fittings at each floor for every riser.
- Hydronic equipment and systems shall not be installed inside BSL-3 containment.

### A.1 Hydronic pipe sizing:

Closed loop hydronic piping shall be sized per the following criteria:

- Piping 100 mm (4 in.) and smaller shall be sized for a maximum velocity of 1.83 m/s (6 fps) and a maximum pressure drop of 0.4 kPa/m (4 ft./100 ft.) of piping.
- Piping larger than 100 mm (4 in.) shall be sized for a maximum velocity of 3.0 m/s (10 fps) and a maximum pressure drop of 0.4 kPa/m (4 ft./100ft.) of piping.

### A.2 Hydronic Pumps:

Hydronic pumps shall be sized and installed to provide ease of maintenance and replacement, and to extend service life. Pumps selection and installation shall include the following:

- The pumping station shall consist, at a minimum, of one prime pump and one stand-by pump. If the pumping station is designed along multiple parallel pumping, then a separate stand-by pump shall be provided.
- Primary distribution pumps shall be base-mounted, end-suction or split-case double-suction. Close-coupled pumps are not acceptable

- Pumps shall be centrifugal type with a max speed of 188 rad/s (1800 rpm)
- In-line pumps shall not exceed 5.6 kW (7.5 HP) in size.
- In-line pumps may be located overhead provided that safe service platforms and permanent rigging devices are installed to accommodate replacement of pumps.
- Each pump shall be provided with its individual starter.
- Isolation valves on suction and discharge lines.
- Pipe strainer or suction diffuser with strainer.
- Flexible connections on suction and discharge. In-line pumps are not to be provided with flexible connectors.
- Check valve on discharge.
- Balancing valve with memory stop on discharge.
- Single pressure gauge with isolation valves to serve both suction and discharge lines.
- Thermometer on suction and discharge lines.

## A.3 Hydronic Coils:

All coils shall be provided with means to: determine water flow, balance water flow, and control the water flow. Large-capacity coils, over 0.63 L/s (10 gpm), shall be provided with pipe-mounted flow meter fittings. Small-capacity coils shall be provided with pressure/ temperature plugs on the supply and return piping.

All terminal coils and equipment shall be provided with two-way control valves. However, three-way control valves may be provided to maintain the minimum water flow required by the variable speed pump. The design water flow of the three-way valve(s) shall match, as close as possible, the minimum water flow of the variable speed pump. These two-way control valves shall be installed on the return water side of the coil

Hydronic coils shall be provided with the following:

- Isolation valves in the supply and return water piping.
- Strainers in the supply water piping.
- Air vents in the supply and return piping if not already provided with the coil.
- Drain valves in the supply and return water piping. These drain valves shall include 19 mm (3/4 in.) hose bibs with caps.

## B. Heating Water Systems:

Heating water systems in NIH buildings shall serve preheat coils; reheat coils; perimeter radiation, fan coil units, etc. These systems can be constant or variable flow and include heat exchangers, duplex distribution pumps, expansion tank(s), makeup water provisions, air separator and two or three way terminal device control valves. Heating water systems shall be designed to offer N+1reliability and maintain 100% capacity in the event a lead

component fails. On large systems, three sets of heat exchangers and pumps shall be provided, two to carry the load and one as standby.

The entire heating water system may be provided in a manufactured package depending on its size. The manufactured package shall be of sufficient size and layout to accommodate service and redundancy requirements of all components and replacement of major parts without shutting off the entire system.

Heating water systems shall be segregated when different water temperatures are required due to seasonal changes. For applications, such as reheat hot water coils (duct mounted, in AHU or furnished with air terminal unit), fan coil units, unit heaters, radiant panels, cabinet unit heaters, convectors, etc., one common heating system shall be provided. Further separation to sub-systems shall be considered only if proven cost-effective by the life-cycle cost analysis. Use of a common heating system requires that care shall be taken to select the lowest hot water temperature reset schedule to offset the generally constant reheat load of the interior spaces.

Heating water systems to serve preheat coils shall have a minimum 40% propylene glycol solution and the preheat coils shall be provided with duplex coil-circulating pumps. Preheat coils shall be designed for parallel flow-circulating.

Coil circulation pumps shall include the following:

- Pumps shall be either in-line or base mounted and located for easy service.
- The coil circulating pumps shall be powered from an emergency power source.

## C. Chilled Water Systems:

Cooling in NIH facilities is to be provided by the used of chilled water. Chilled-water cooling coils shall be selected to ensure that the interior space relative humidity is maintained at full and part-load conditions. Chilled water coils shall be selected for an entering water temperature of 7.2°C (45°F) and leaving water temperature of 15.6°C (60°F) at peak demand.

### C.1 Chilled water Systems for Bethesda and Poolesville:

Chilled water systems for buildings in the Bethesda campus and Poolesville north campus shall be provided from the existing chilled water site distribution system. Connection to the site distribution piping system shall be achieved by extending the utility tunnel to the building wall except that up to 30 m (100 ft.) of direct buried pre-insulated pipe may be used between the building and utility tunnel.

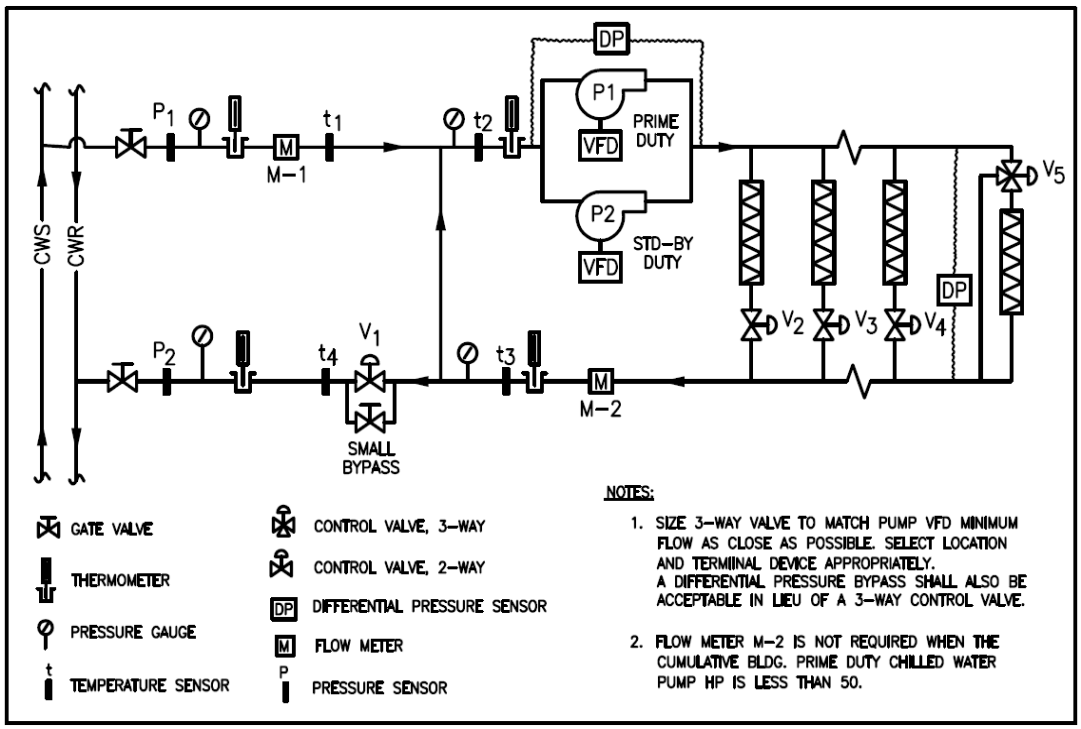
Isolation valves with tamper switches to indicate valve position (open and closed) shall be provided at the point where the chilled water distribution piping enters the building.

The terms primary, secondary and tertiary piping distribution systems refer to the following:

- Primary: Piping distribution at the central chiller plant.
- Secondary: Site (campus) piping distribution.
- Tertiary: Piping distribution within an individual building connected to the site loop.

Individual buildings on the Bethesda and Poolesville campuses shall each be provided with a tertiary, variable speed chilled-water pumping system.

For large facilities with floor areas greater than a gross 9,290 $m^2$ (30,000 $ft^2$), consideration shall be given to providing multiple building chilled-water services to the building's tertiary pumping system.




Building Tertiary Pumping System Schematic

## C.2 Special Purpose Chilled Water System:

Special purpose chilled water systems used in NIH buildings may include dedicated chilled water systems for special areas such as operating rooms and computer rooms as well as fan coil units utilized for supplemental cooling. The operating temperatures of these sys-

tems shall closely follow that of the plant chilled-water so that secondary equipment efficiency is optimized.

Chilled water systems dedicated to special areas, such as operating rooms and computer rooms, may be hydraulically separated from the building piping distribution system, and provided with a dedicated pumping station.

Special areas of critical nature, which must remain in operation continuously, shall be provided with supplemental chiller(s) to back-up the central system. Supplemental chillers may be in direct contact with the building tertiary loop or connected trough heat exchangers, as the specific application dictates. Systems serving areas of critical nature shall offer 100% redundancy for all vital components and shall be powered from an emergency power source.

## C.3 Process Cooling Water:

Plant chilled water may be used for process cooling provided that the required temperature and pressure is similar to the building requirements. This process cooling water can be by the same tertiary loop as the rest of the building. If the process cooling demand is not similar, a separate tertiary loop may be provided. Process cooling water may be generated through one of the following methods:

- Water to water heat exchanger using plant chilled water
- Dx water cooled chiller (Air cooled chillers are not allowed.)

When the process chilled water is generated with a supplemental water cooled chiller, condenser water shall be either plant chilled water or condenser water from a cooling tower.

If plant chilled water is used for condensing, a separate tertiary loop shall be provided if the process demand doesn't have the same pressure and temperature requirements as the building demand. Redundancy of critical components and emergency power shall be provided where required by the program.

## D. Steam systems:

Steam systems at NIH facilities are extensive and serve a variety of equipment and systems such as: sterilizers, autoclaves, cage washing equipment, HVAC systems, domestic hot water, etc. Refer to section 6-2 "Air-Handling Systems" for allowed uses of central plant steam and need of clean steam systems.

NIH steam systems and distribution piping are classified as follows:

- Low-pressure steam: 138 kPa (20 psi) and below.

- Medium-pressure steam: 145 kPa (21 psi) through 552 kPa (80 psi)
- High-pressure steam: 558 kPa (81 psi) and above.

In the NIH Bethesda campus, steam is generated at the central steam plant in Building 11 and distributed at a pressure of 1,138 kPa (165 psi). Steam condensate is collected and returned to Building 11 through a series of low-pressure pumped return mains and high-pressure drip condensate piping.

Steam to the equipment listed below shall be supplied at the indicated steam pressure:

- Air heating coils: 97 kPa (15 psi) maximum (higher pressures may be used if justified by engineering or economic considerations).
- Central humidifiers within air-handling units: 97 kPa (15 psi) maximum.
- Convectors: 97 kPa (15 psi) maximum.
- Dietetic equipment: as specified by equipment manufacturer.
- Domestic hot water heaters: 552 kPa (80 psi) maximum.
- Heating water heat exchangers: 552 kPa (80 psi) maximum.
- Duct mounted humidifiers: 97 kPa (15 psi)
- Radiators: 97 kPa (15 psi) maximum.
- Sterilizers and washers: as specified by equipment manufacturer.
- Unit heaters: 207 kPa (30 psi) maximum.

Radiators, convectors, air-heating coils, and unit heaters shall generally be supplied with heating water in lieu of steam.

Steam supply and steam condensate return distribution systems shall be sized conservatively with minimal line pressure loss at maximum design load plus allowances for warm-up and future growth. All valves, traps, equipment, and specialties shall be selected and sized for their intended use and shown in the construction documents. Sizing considerations shall include warm-up factors and estimated inlet and outlet pressure. Steam condensate shall be collected and returned to the central steam plant.

The use of service tunnels, pipe trenches, and direct burial shall be considered for steam/condensate distribution. Insulation alternatives shall be optimized for energy savings.

## D.1 Steam Pressure Reducing Valve Station:

Steam pressure reducing (PRV) stations shall be provided near the steam service entrance into the building. PRV pressure reducing stages shall be as follows:

- Medium to low: 552 kPa (80 psi) to 97 kPa (15 psi)

- Medium to medium: 552 kPa (80 psi) to 276 kPa (40 psi)
- High to medium: 1,138 kPa (165 psi) to 552 kPa (80 psi)

Secondary and/or remote PRV's, within the building, should be avoided. Second-stage PRVs may be installed in mechanical penthouses/rooms or other easily accessible mechanical spaces. Small PRVs, that serve isolated equipment such as glass washers with different pressure requirements, may be installed close to the equipment being served, provided that it is located in a service corridor or other accessible and suitable space.

PRV stations shall be sized for the calculated peak demand. For process equipment load, the PRV shall be sized, as a minimum, for 100% steam consumption of the largest single user plus 25% steam consumption of all other users.

Where a single PRV would exceed 75 mm (3 in.) in size or the turndown ratio (maximum load/minimum load) is greater than 10:1, two PRVs shall be provided in parallel, one for approximately 0 to 33% for low-load conditions and one for 33 to 100% for high-load conditions, with a single full pipe size bypass. In no case shall high-pressure steam be reduced in a single stage to 276 kPa (40 psi) or less.

For large PRVs where valve sizes would exceed 150 mm (6 in.), three PRVs shall be provided in parallel, one for approximately 0 to 33% for low-load and two for 33 to 100% for high-load conditions with a single bypass.

Bypass valves shall have two isolation valves; the first valve to secure steam (globe valve) and the second valve to modulate pressure.

Where the steam service includes capacity for future expansion, all PRV station piping and components, except the PRVs, shall be sized for the future. The PRV shall be sized for the present load. Install eccentric reducers before PRV and a concentric reducer after the valve shall be provided so that condensate does not collect within the station.

PRV stations and headers shall be fabricated using fully welded fittings and flanged valves. The high-pressure main shall have a single shutoff valve capable of securing all steam to the building. Each branch of the PRV station shall have a single shutoff valve capable of securing steam without approaching the station. PRV stations shall be isolated from the structure to limit structure-borne noise. The maximum valve NC level shall not exceed that specified at all anticipated loads.

PRVs shall be fitted with removable custom fabric insulation jackets to further reduce noise and heat gain to the space. Insulation jackets shall be equipped with straps and buckles to

allow frequent removal and reinstallation without damaging the insulation. Steam valve pilot lines shall be sloped down to tie into mains and shall be contained within isolation shutoff valves. Pilot lines shall be at least 13 mm (0.5 in.) in diameter to prevent clogging.

## D.2 Steam Condensate Return Units:

Steam Condensate receivers shall serve only low-pressure mains and the discharge from flash tanks. Receivers shall not be used as flash tanks or have high or medium pressure condensate directly piped, regardless of capacity. High and medium pressure steam condensate return shall be piped to separate flash tanks.

Condensate return units shall be duplex electric, steam, or compressed-air powered. Pumps shall have Viton seals and stainless steel shafts. Each pump shall have isolation valves on both the inlet and discharge lines to accommodate service. Each condensate return unit shall be piped with a full-size bypass line to drain. The bypass shall serve as emergency manual drainage for condensate if the return unit is off line. The bypass shall be indirectly piped to the sanitary system and have a cooling trap to temper condensate down to a suitable temperature prior to discharge. All condensate receivers shall be vented outdoors and independent of other steam relief vents. Condensate return units shall have fully packaged controls, starters, alternators, disconnects, and high-level alarms tied to the building automation system.

Pump motor starters shall be clearly identified and, where practical, shall be mounted on a common panel. If a duplex condensate pump is installed in the pit, the starter, disconnect switch, and alternator are to be located above the pit where easily accessible. Locating any serviceable equipment in a confined space shall be avoided.

## D.3 Steam Traps:

Steam traps shall be sized for the particular application. Refer to exhibit X6-3-E for a list the specific steam traps to be used for the different steam applications as well as the associated safety factors to be used in the selection of steam traps.

Trap bypass valves shall not be installed; if redundancy or additional capacity is required, dual traps shall be installed.

All traps, except those on radiation heating equipment, shall be located a minimum 150 mm (6 in.) below the equipment they service.

## D.4 Steam and Condensate Piping Systems:

Piping shall be designed and installed to allow for expansion and contraction without creating excessive stresses and strain in the piping system. Expansion loops, offsets, pipe guides, and anchors shall be shown on the contract documents. Expansion joints shall be provided as a last resort. Pipe anchors shall be designed for each location and sized to handle all forces with conservative safety factors. All anchors, guide loops, and joints shall be readily accessible for maintenance and inspection.

Steam and steam condensate piping, within NIH buildings, shall be sized in accordance with the parameters in the following table:

| Steam and Steam Condensate Piping Design Criteria | | | | | |
|---|---|---|---|---|---|
| Steam Pressure Service | Steam Supply Mains and Risers | | | Steam Condensate Return Mains and Risers | |
| | Maximum Total System Pressure Drop (Note 1) % | Maximum Friction Rate kPa/m (psi/100 ft.) | Maximum Steam Velocity (Note 2) m/s (fpm) | Maximum Total System Pressure Drop (Note 1) % | Maximum Friction Rate kPa/m (psi/100 ft.) |
| High-pressure 558 kPa (81 psi) and above | 10 | 0.50 – 2 (2 – 8) | 50 (10,000) | 10 | 0.50 (2) |
| Medium-pressure 145 kPa (21) to 552 kPa (80 psi) | 5 | 0.50 (2) | 40 (8,000) | 5 | 0.25 (1) |
| Low-pressure 145 kPa (20 psi) and below | 5 | 0.50 (2) | 30 (6,000) | 5 | 0.10 (0.5) |

*(1) Percentage of initial system pressure for supply or return mains*
*(2) The need for higher steam velocity needs to be reviewed by NIH*

Regardless of steam and condensate pressure classification, all pipe and fittings shall be rated for minimum pressure of 2,067 kPa (300 psi). Steam piping shall be a minimum Schedule 40 and condensate piping a minimum Schedule 80. Steam connections to equipment 50 mm (2 in.) and larger shall be flanged and shall be threaded for sizes 38 mm (1.5 in.) and smaller. Flange gaskets and bolts shall be suitable for operating pressures and temperatures of the system. Hardware shall be selected so that temperature and pressure fluctuations in the system and expansion/contraction do not affect performance over time.

Condensate piping shall be gravity drained from the trap to the condensate receiver for all low pressure steam applications. Traps on steam coils shall be at least 450 mm (18 in.) below the coil discharge. Where the hydraulic head is not achievable, condensate pumps shall be utilized. Under no circumstances shall condensate be lifted after a steam modulating device.

Drip legs shall be provided in all steam mains to accommodate condensate drainage at all locations. Drip connections shall be provided at the base of each low point in mains and just before all equipment connections. Drip legs shall be provided in steam piping prior to connecting to laboratory process equipment to prevent the build up of steam condensate. Steam condensate shall drain away from laboratory process equipment. Steam instrumentation sensors require a 6 m (2 ft.) long sensing line from header to sensor to protect it from extensive heat.

High-pressure drip lines on steam distribution mains shall be routed to flash tanks and not connected to pumped return lines to plant. High-pressure and medium-pressure condensate shall be piped independently to an individual building's flash tanks before connection to the condensate receiver. Flash tanks shall be factory fabricated and ASME stamped and approved. Contractor shop-fabricated tanks are not acceptable.

Steam control valves shall be fully proportional with modulating equal percentage plug. Steam valves shall be designed to modulate and be sized to meet loads at full and partial loads. All steam control valves shall have stainless steel trim and be suitable for the pressure condition and shall operate with the differential pressure required. Control valves serving coils and heat exchangers shall be provided with one-third/two-thirds control valves arrangements where control is critical or capacity is large.

Steam valves and specialties shall be of the industrial high-performance type. Positive shutoff and isolation of mains are critical to the safety of maintenance personnel. Stainless steel seats and disk are required. Shutoff gate valves shall be used in all steam and condensate lines (required use of OS&Y 300# ANSI for high pressure and 150# ANSI for medium and low-pressure system). Bronze stemmed gate valves manufactured by Grinnel, Vale and Jenkins are recommended for use at the NIH campus. All valve stems on systems to be insulated shall be provided as extended type as required to permit sufficient clearance for proper operation without damaging insulation.

Steam safety relief valves shall be piped individually and discharged no less than 2.1 m (7 ft.) above the building roof. Care shall be taken not to locate discharges close to outdoor air intake or where they could be a hazard to maintenance personnel. Relief valves shall not

be connected to other steam vents. All valves, drip-pan elbows, and relief lines shall meet ASME requirements.

Warm-up valves shall be provided to bypass shut-off valves on each main larger than 75 mm (3 in.).

Steam strainers shall be positioned horizontally (flat) to prevent condensate from collecting in the bottom of the strainer and reducing its life.

Steam vacuum breakers, not check valves, shall be used on coils and heat exchangers to eliminate vacuum. Vacuum breakers shall be located external to air-handling unit casing.

Steam pressure gauges shall be liquid filled with a range consistent with operating pressure. Stainless steel ball valves shall be used for gauge cocks.

## E. Piping:

### E.1 Piping Designation, Material, Fittings, and Joints:

Piping designations, material, fittings and Joints shall be as indicated in Exhibit X6-3-A, Exhibit X6-3-B, and Exhibit X6-3-C, and Exhibit X6-3-D

Selection of pipe materials and installation method shall incorporate special requirements unique to individual program areas, such as consideration of magnetic fields, special materials, shielding, as well as all types of chemical exposure, etc.

Type L (Hard-drawn) wall thickness tubing may be used in lieu of Type K (Hard-drawn) for copper piping for above ground water piping installations serving extramural projects located outside of the metropolitan Washington DC area if prevailing practice and water supply conditions are compatible with Type L (Hard-drawn) copper tubing. Water piping installation at NIH Bethesda Campus and Poolesville facilities shall utilize Type K (hard-drawn) tubing as indicated in Exhibit X6-3-A.

Drain Trap material selection shall be done in consideration of the different products to be disposed into the sewage system. Disposal of chloride containing products, into the sewage system, has been identified as one of the causes for pitting problems in sewage systems made of 316 stainless steel. Please refer to the link below for a copy of a document about this issue.
http://orf.od.nih.gov/PoliciesAndGuidelines/Bioenvironmental/

## E.2 Piping Installation:

The minimum pipe size shall be 19 mm (0.75 in.) for HVAC systems. Size reductions may occur only immediately adjacent to equipment connections and at tee pipe fittings.

Valves and specialties serving equipment shall be full pipe size, not the reduced equipment connection size, except where engineering calculations necessitate a different size.

No piping shall penetrate ductwork. Unions or flanges on each side of all pieces of equipment, and other similar items, shall be designed in such a manner that they can be readily disconnected. Unions and flanges shall be placed in a location that shall be accessible after completion of the project. Piping and conduits, except electrical conduits run within floor construction, shall be designed to run parallel to building structure.

Hydronic and steam piping shall not be located with in electrical rooms and secondary switchgear rooms. In the event that this can not be avoided, protection such as drip pans shall be provided beneath all piping and equipment. These drip pans shall be provided with water detection alarms connected to the BAS. This piping and drip pans shall never be located over any electrical transformer, electrical panels, and switchgear.

The different service pipes, valves, and fittings shall be installed so that, after the insulation/jacketing is applied, there shall not be less than 25 mm (1 in.) clear space between the finished jacketing and other work, and between the finished jacketing and parallel adjacent pipes.

Dissimilar ferrous piping material shall only be connected to each other through a dielectric fitting, union, joint or coupling that is in compliance with applicable codes and compatible with pipe materials on both sides as well as the liquid being conveyed through the pipe.

## E.3 Hangers and Supports:

Materials and application of pipe hangers and supports shall conform to the latest requirements of ANSI/ASME B31.1 or ANSI/ASME B31.9 and MSS Standard Practice SP-58, SP-69, and SP-89, and appropriate Master specifications and Federal specifications where applicable. All materials and anchorage methods for installations in Seismic Zones 3 and 4 shall comply with local building code requirements, and shall utilize materials and methods approved by the local agency having jurisdiction. Hangers in close proximity, on different service lines, running parallel with each other, shall be in line with each other and parallel to the building structure. Hangers shall be:

- Spaced to prevent sagging and permit proper pipe drainage.

- Spaced not more than 2.4 m (8 ft.) apart, unless a greater spacing is specifically designed.
- Placed within 300 mm (1 ft.) of each horizontal elbow.

Vertical runs of pipe and conduit less than 4.6 m (15 ft.) long shall be supported by hangers placed 300 mm (1 ft.) or less from the elbows on the connecting horizontal runs. Vertical runs of pipe and conduit over 4.6 m (15 ft.) long, but not over 18.3 m (60 ft.) long, and not over 150 mm (6 in.) in size, shall be supported by heavy steel clamps.

- Clamps shall be bolted tightly around the pipes and conduits and shall rest securely on the building structure without blocking.
- Clamps may be welded to the pipes and placed below coupling.

In lieu of individual hangers, multiple (trapeze) hangers for accessible piping shall be considered for water pipes having the same elevation and slope and for electrical conduits. Each multiple hanger shall be designed to support a load equal to the sum of the weights of the pipes, conduits, wire, and water and the weight of the hanger itself, plus 90 kg (200 lbs). The structural engineer shall approve the structural loads caused by the installation of large-diameter piping, 200 mm (8 in.) and larger. Safety factors shall be in accordance with ANSI/ASME B31.1. Loading on anchors shall not exceed 25% of the proof load test. The size of the hanger rods shall be such that the stress at the root of the thread shall not be over 68,950 kPa (10,000 psi) at the design load. No rod shall be smaller than 9 mm (3/8 in.). The size of the horizontal members shall be such that the maximum stress shall not be over 103,425 kPa (15,000 psi) design load. Where vertical piping is specified to extend through sleeves, the riser clamp or pipe support shall transverse the sleeve directly to structure. Trapeze hangers supporting large-diameter piping, 200 mm (8 in.) and larger, shall be placed to load joists at top panel points only.

Roller-type pipe supports shall be specified where significant horizontal pipe movement will occur as a result of thermal expansion, and spring-type supports shall be specified where significant vertical movement will occur and where vibration isolation is critical.

Plastic piping shall be supported to permit proper movement and prevent stresses from expansion and contraction, as well as to protect from damage to piping from abrasion.

Fireproofing shall not be damaged by the installation of any hanger or attachment. Where existing fireproofing is disturbed, it shall be restored to the satisfaction of the DFM.

## E.4 Thermal Expansion:

Steam, condensate, and other hot service piping shall be designed with loops, bends, and offsets to allow for thermal expansion and keep pipe stresses within the allowable limits of the piping material. Expansion joints or ball joints shall be avoided. Expansion loops are preferred. Thrust restraints shall be specified to prevent pipe blowout or pipe joint separation due to test procedures or system thrust loads.

## E.5 Welding:

Welding shall conform to current standards and recommendations of the National Certified Pipe Welding Bureau and all OSHA, state protection, and NFPA Standard 241 requirements.

## E.5.a Welding of Hydronic Piping:

Welded valves used in the main campus distribution systems and all pipe connections (both butt-welds and socket-welds types) shall conform to ASME B31.9. Butt-welded fittings shall conform to ASME B16.9. Socket-welded fittings shall conform to ASME B16.11. Welded fittings shall be identified with the appropriate grade and marking symbol.

## E.5.b Welding of Steam and Steam Condensate Piping:

Welding of joints in piping, butt welds, fillet welds, bends, loops, offsets, and preparation and cleaning of pipe shall be in accordance with ASME B31.1. Welds shall be visually examined and meet acceptance standards indicated in Chapter VI of ASME B31.1. Quality of welds, correction of defects, stress relieving, and preheating shall be in accordance with ASME B31.1. Steam piping systems with operating pressure 138 kPa (20 psi) or less and associated condensate piping may be welded in conformance to ANSI B31.9. Arc Welding and Gas Welding shall be in accordance with ASME BPVC SEC IX.

## E.6 Brazing and Soldering:

Brazing and soldering procedure qualification shall conform to ASME B31.1. Brazing procedure for joints shall be as outlined in the CDA A4015. Soldering, soldering preparation, and procedures for joints shall be in accordance with ASME B31.1 and as outlined in the CDA A4015.

## E.7 Piping and Equipment identification:

All mechanical and electrical equipment and systems shall be provided with a complete identification system that conforms to the requirements published in ANSI/ASME Standard 13.1 and NFPA 99. All control devices, i.e., panels, switches, starters, pushbutton stations, relays, temperature controls, etc., shall be clearly identified as to their function and the

equipment controlled. Equipment/valves identification and numbering shall be coordinated with the NIH maintenance staff.

In existing buildings, identification systems need to match already existing identification system. The A/E shall verify the actual color configuration used in the existing building during the design phase of the project. Refer to exhibit X6-3-A for color coding used in some of the existing buildings.

Identification shall be system specific, i.e., "Potable or Domestic Cold Water," "Industrial or Laboratory Cold Water," "Plant Air," etc. In no case shall piping be identified with generic terms, i.e., "cold water," "hot water," etc. Each laboratory water outlet shall be provided with a laminated identification sign that reads "Laboratory Water—Do Not Drink". Similar signage shall be provided for use at ice machines in laboratories and water faucets on non-potable water systems.

Where items requiring routine service are concealed above ceilings or behind access doors, a suitable and visible label shall be attached to the surface to identify the location of such items.

Equipment markers shall be provided for all equipment such as pumps, fans, vav boxes, fan coil units, heaters, air-handling units, boilers, chillers, etc. Equipment markers shall clearly identify the equipment and space or duty they serve. Equipment markers shall consists of engraved, laminated, black-and-white phenolic legend plates. White letters shall be, at least, 19 mm (0.75 in.) high on surrounding black plate

Piping labels shall consists of colored, pre-rolled, semi-rigid plastic labels with black letters set around pipes with a field-installed high-strength cement compound applied along their longitudinal edge. Piping labels shall have 13 mm (0.5 in.) high black letters for pipes smaller than 25 mm (1 in.) and, at least, 19 mm (0.75 in.) high letters for pipes 25 mm (1 in.) and larger. Piping labels shall include flow arrows.

Piping labels shall be placed around each pipe, with or without insulation, every 9 m (30 ft.). Additional piping labels shall be placed within rooms smaller than 4.5 m (15 ft), and on each side of a wall or floor penetration. Additional pipe labels shall be placed within 2 m (6 ft.) of every major pipe valve, every connected piece of equipment, and at the point where the piping enters every floor.

Valve tags shall be provided for all valves. Valve tags shall consist of colored plastic, brass, or aluminum valve tags with stamped-in numbers. Tags shall be secured to the valve with a metal chain. Valve tags are not required on shut-off valves for individual fixtures or equip-

ment where their function is obvious, or where the fixture or equipment is immediately adjacent. Valve tags shall be round of at least 38 mm (1.5 in.) in diameter with white text indicating the associated system and the valve number.

## 6-3-10 Design Guidance (Reserved)

## 6-3-20 Design Information (Reserved)

## 6-3-30 Design Documents Requirements

### A. Piping and Equipment Identification:

Contract documents shall require that the contractor complies with the following:

- Exercise care in scheduling and selecting valve numbers. The number sequence shall be specific and continuous with individual piping services; that is, domestic water system valves are always identified as 1.1, 1.2, 1.3, etc. and other distinctly different piping systems shall have another number series.
- Prepare schematic drawings of each floor to show the approximate locations, identity, and function of all tagged service and control valves.
- Include a copy of each drawing and schedule in the operations and maintenance manuals.
- Identify, by means of stenciling, the construction date of sanitary and vacuum piping at the point of connection of any new to existing piping distribution system.

### B. Testing:

Construction documents shall include specifications for testing procedures and commissioning of all systems installed in the project. Testing procedures shall include the following:

- Comply with all applicable codes
- Demonstrate that systems meet the requirements in the construction documents.
- Water sampling to verify water treatment, pipeline sterilization.
- Pressure and leak testing

| Pipe Service, Service Designation, Color Code, Material, Fittings and Joints | | | | | | |
|---|---|---|---|---|---|---|
| Line item | Pipe Service (Note 22) | Service Designation Abbreviation | Color Code | Pipe Material Type | Pipe Fitting Type | Pipe Joint Type |
| 1. | General Sanitary Waste and Vent (except for kitchen, lab, and vivaria waste) | SAN, V | Green | | | |
| a. | Above and below ground - All sizes | | | A[1] | I | a |
| b. | Above and below ground - 375 mm (15 in.) and smaller (except kitchen or grease waste) | | | B[1]<br>D<br>Q[4] | II<br>IV<br>VIII | a<br>c<br>e |
| c. | Above and below ground - 450 mm (18 in.) and larger | | | C | III | b, j[7], v[19] |
| d. | Vent piping | V | | A/B<br>D<br>Q | I/II<br>IV<br>VIII | a<br>c, d<br>e |
| e. | Aboveground trap arms and indirect waste | | | D<br>Q[4] | IV<br>VIII | c<br>e |
| f. | Sanitary trap primer lines | TP | | Q, R | XVIII | E, L |
| g. | Pumped sanitary waste above and below ground - 100 mm (4 in.) and smaller | PSAN | | Q | XVIII, VIII | E |
| h. | Pumped sanitary waste above and below ground - 150 mm (6 in.) and larger | PSAN | | C | III | j, v[19] |
| i. | Pumped sanitary waste aboveground all sizes | PSAN | | AA | IX | K |
| j. | Sanitary laterals outside building to point of connection with site sewer, subject to vehicular or extreme trench loads | | | C | III | b, j[7] |
| k. | Sanitary waste piping located above food preparation areas, food storage rooms, and surgical areas. | SAN | | Note 2 | Note 2 | Note 2 |
| l. | Vapor vents from oil interceptors | VV | | D | IV | c |
| m. | Autoclave and similar high temperature, non-corrosive waste (including units with after coolers), no DI rinse | SAN | | A/B<br>D<br>Q | I/II<br>IV<br>VIII | a<br>c<br>e |
| 2. | Kitchen Waste and Grease Waste | SAN and GW | Green | | | |
| a. | Underground and Aboveground | | | E[15] | V | g/h |
| b. | Underground | | | F | VI | i |
| c. | Aboveground waste and vent | | | B[3]<br>F/G | II<br>VI/VII | a<br>i |

| Pipe Service, Service Designation, Color Code, Material, Fittings and Joints | | | | | | |
|---|---|---|---|---|---|---|
| Line item | Pipe Service (Note 22) | Service Designation Abbreviation | Color Code | Pipe Material Type | Pipe Fitting Type | Pipe Joint Type |
| d. | Aboveground vent | | | D<br>Q | IV<br>VIII | c<br>e |
| e. | Aboveground exposed waste, traps, and trap arm | | | Q[4] | VIII | e |
| 3. | Laboratory/ Cagewash/ Vivarium/ Photo Processing/ Spaces Subject to Corrosive Detergents/ General Corrosion Resistant Waste and Vent[2] | LW, CRW, LV, CRV | Green | | | |
| a. | Underground waste | | | E[15]<br>H | V<br>X | g, h<br>o, m, p |
| b. | Underground and above ground waste and vent | | | PP | XXXVII | m |
| c. | Aboveground waste and vent | | | E[15]<br>J[5]<br>I | V<br>XI<br>XII | g, h<br>n<br>m, o, p |
| d. | Corrosion resistant waste piping located above food preparation areas, food storage rooms, and surgical areas. | | | Note 2 | Note 2 | Note 2 |
| e. | Laboratory waste from cagewash equipment, sterilizers, and similar equipment with potential high temperature discharge (including units with after coolers) | | | E[15]<br>J<br>PP[9] | V<br>XI<br>XXXVII | g,h<br>n<br>m, p |
| f. | Lab/corrosion resistant waste trap primer lines | TP | | FF | XIII | g |
| g. | Pumped corrosive/lab waste | PCRW | | H | X | m, p |
| h. | Corrosive indirect waste | | | I, FF, K, L | XIII | q |
| i. | Lab waste for animal holding areas | | | Note 10 | Note 10 | Note 10 |
| 4. | Biohazardous Waste and Vent | | Green | Note 20 | Note 20 | Note 20 |
| 5. | Storm Water and Miscellaneous Clear Water Waste | SD, CWW | Green | | | |
| a. | Gravity above and below ground - 400 mm (16 in.) and smaller | | | A[1],B[1]<br>D | I,II<br>IV | a<br>c |
| b. | Gravity above and below ground - 450 mm (18 in.) and larger | | | O[1] | XVI | b, j[7], v[19] |
| c. | Gravity aboveground | | | Q | VIII | e |

| Pipe Service, Service Designation, Color Code, Material, Fittings and Joints | | | | | | |
|---|---|---|---|---|---|---|
| Line item | Pipe Service (Note 22) | Service Designation Abbreviation | Color Code | Pipe Material Type | Pipe Fitting Type | Pipe Joint Type |
| d. | Pumped above and below ground - 100 mm (4 in.) and smaller | PSD, PD | | Q | VIII, XVIII | e |
| e. | Pumped above and below ground - 150 mm (6 in.) and larger | PSD, PD | | O | XVI | j, v[19] |
| f. | Pumped aboveground – all sizes | PSD, PD | | AA | IX | k |
| g. | Storm sewer laterals outside building to point of connection with site sewer subject to vehicular or extreme trench loads. | | | O | XVI | b, j[7] |
| h. | Storm water and clear water drain lines located above food preparation areas, food storage rooms, and surgical areas. | | | Note 2 | Note 2 | Note 2 |
| 6. | Foundation Drain/Subsoil Drainage | SSD | n/a | P<br>QQ | XVII<br>XIV | s<br>f |
| 7. | Condensate Drain (from cooling coil drain pan) | CD | Yellow | Q<br>AA | VIII<br>IX | e<br>k |
| 8. | Incoming Combined Water Service/ Domestic Water Service/ Fire Service | W, DW, FS | Green | | | |
| a. | Aboveground - 62 mm (2.5 in.) through 100 mm (4 in.) | | | T | XVIII | L |
| b. | Aboveground - 100 mm (4 in.) and larger | | | V | XIX | u[8], v |
| c. | Underground - 75 mm (3 in.) and larger | | | X | XXI | t |
| d. | Underground - 75 mm (3 in.) and smaller | | | U | XVIII | L[6] |
| 9. | Domestic Cold Water, Makeup Water for Closed Loop Systems and Laboratory, Process and Non-potable Cold Water | DCW, LCW, NPC | Green | | | |
| a. | Aboveground - 62 mm (2.5 in.) and smaller | | | T[17]<br>Z<br>Y | XVIII<br>XXIII<br>XXII | W<br>K<br>x |
| b. | Aboveground - 75 mm (3 in.) through 200 mm (8 in,) | | | T[17]<br>Y | XVIII<br>XXII | L<br>x |
| c. | Aboveground - 150 mm (6 in.) and larger | | | V<br>W<br>Y | XIX<br>XX<br>XXII | u[8]<br>v<br>x[8] |
| d. | Underground – 62 mm (2.5 in.) and smaller | | | U | XVIII | L[6] |

| Pipe Service, Service Designation, Color Code, Material, Fittings and Joints | | | | | | |
|---|---|---|---|---|---|---|
| Line item | Pipe Service (Note 22) | Service Designation Abbreviation | Color Code | Pipe Material Type | Pipe Fitting Type | Pipe Joint Type |
| 10. | Domestic, Laboratory, Process and Non-potable Hot Water and Hot Water Recirculation | DHW, DHR,LHW, LHR, NPH, NPHR | Yellow | | | |
| a. | Aboveground - 62 mm (2.5 in.) and smaller | | | T[17]<br>Z<br>Y | XVIII<br>XXIII<br>XXII | w<br>k<br>x |
| b. | Aboveground - 75 mm (3 in.) through 200 mm (8 in.) | | | T[17]<br>Y | XVIII<br>XXII | L<br>x |
| c. | Aboveground - 150 mm (6 in.) and larger | | | Y<br>W | XXII<br>XX | x[8]<br>v |
| 11. | Purified Animal Drinking Water | ADW | Green | BB<br>CC | XXIV<br>XXV | y<br>z |
| 12. | Softened Water | SW | Green | | | |
| a. | Aboveground - 62 mm (2.5 in.) and smaller | | | T[17] | XVIII | w |
| b. | Aboveground - 75 mm (3 in.) through 150 mm (6 in.) | | | T[17] | XVIII | L |
| 13. | High Purity Water Supply and Return, Water Quality Levels Type II and Type III | HPWS/ HPWR Note 21 | Green | DD | XXVI | aa |
| 14. | High Purity Water Supply and Return, Water Quality Level Type I | Note 21 | Green | EE | XXXII | aa |
| 15. | Distilled Water | DIS | Green | EE | XXXII | aa |
| | | | | | | |
| 16. | Chilled Water Supply and Return | CHWS/ CHWR | Green | | | |
| a. | 650 mm (26 in.) and larger | | | MM | XXIX | r |
| b. | 300 mm (12 in.) through 600 mm (24 in.) | | | JJ | XXIX | r |
| c. | 62 mm (2.5 in.) through 250 mm (10 in.) | | | II | XXIX | r |
| d. | 62 mm (2.5 in.) to 250 mm (10 in.) | | | II<br>Q | XXXIII<br>XVIII | ee[8]<br>L |
| e. | 50 mm (2 in.) and smaller | | | II<br>Q | XXVIII<br>XVIII | k<br>e, L |
| 17. | Glycol Water Supply and Return | GWS/GWR | Green | | | |
| a. | 62 mm (2.5 in.) and larger | | | II | XXIX | r |

| Pipe Service, Service Designation, Color Code, Material, Fittings and Joints | | | | | | |
|---|---|---|---|---|---|---|
| Line item | Pipe Service (Note 22) | Service Designation Abbreviation | Color Code | Pipe Material Type | Pipe Fitting Type | Pipe Joint Type |
| b. | 50 mm (2 in.) and smaller | | | II<br>Q | XXVIII<br>XVIII | k<br>e, L |
| 18. | Condenser Water Supply and Return | CWS/CWR | Green | | | |
| a. | 300 mm (12 in.) and larger | | | JJ | XXIX | r |
| b. | 62 mm (2.5 in.) through 250 mm (10 in.) | | | II<br>II | XXIX<br>XXXIII | r<br>ee[8] |
| c. | 50 mm (2 in.) and smaller | | | Q | XVIII | e, L |
| 19. | Cooling Water Supply and Return (Process Cooling) | CS/CR | Green | | | |
| a. | 125 mm (5 in.) and larger | | | II | XXIX | r |
| b. | 100 mm (4 in.)and smaller | | | Q | XVIII | e, L |
| c. | 62 mm (2.5 in.) to 150 mm (6 in.) | | | II | XXXIII | ee[8] |
| 20. | Heating Water Supply and Return and Heat Recovery Supply and Return | HWS/ HWR | Yellow | | | |
| a. | 300 mm (12 in.) and larger | | | JJ | XXIX | r |
| b. | 62 mm (2.5 in.) through 250 mm (10 in.) | | | II | XXIX | r |
| c. | 50 mm (2 in.) and smaller | | | II<br>Q | XXVIII<br>XVIII | k<br>e, L |
| 21. | Steam Supply, 1200 kPa (175 psi) Maximum | HPS/ MPS/LPS | Yellow | | | |
| a. | 300 mm (12 in.) and larger | | | LL | XXIX | r |
| b. | 62 mm (2.5 in.) through 250 mm (10 in.) | | | KK | XXIX | r |
| c. | 50 mm (2 in.) and smaller | | | KK | XXXIV<br>XXVIII | k |
| 22. | Steam Vents | SV | Yellow | | | |
| a. | 62 mm (2.5 in.) and larger | | | KK | XXIX | r |
| b. | 50 mm (2 in.) and smaller | | | KK | XXXIV<br>XXVIII | k |
| c. | 50 mm (2 in.) and smaller (optional) | | | KK | XXXV | r |
| 23. | Steam Condensate (gravity return) | HPR/ MPR/LPR | Yellow | | | |
| a. | 62 mm (2.5 in.) and larger | | | LL | XXIX | r |
| b. | 50 mm (2 in.) and smaller | | | LL | XXXIV<br>XXVIII<br>XXXV | k<br>k<br>r |

| Pipe Service, Service Designation, Color Code, Material, Fittings and Joints | | | | | | |
|---|---|---|---|---|---|---|
| Line item | Pipe Service (Note 22) | Service Designation Abbreviation | Color Code | Pipe Material Type | Pipe Fitting Type | Pipe Joint Type |
| 24. | Pump Steam Condensate | PC | Yellow | M[16] | XV | r |
| 25. | Oxygen (gaseous, non-cryogenic) | O2 | Green/ White | | | |
| a. | Aboveground | | | GG | XXVII | bb |
| b. | Underground | | | HH[11] | XXVII | bb |
| 26. | Nitrogen (gaseous, non-cryogenic) | N2 | Black/ White | | | |
| a. | Standard pressure | | | GG | XXVII | bb |
| b. | High pressure, over 1000 kPa (150 psi) | | | HH | XXVII | bb |
| 27. | Nitrous Oxide (gaseous, non-cryogenic) | N20 | Blue/ White | GG | XXVII | bb |
| 28. | Carbon Dioxide (gaseous, non-cryogenic) | CO2 | Gray/ Black | | | |
| a. | Aboveground | | | GG | XXVII | bb |
| b. | Underground | | | HH[11] | XXVII | bb |
| 29. | Argon, Inert Gasses, and CO2/Air/Oxygen Mixtures | | | GG | XXVII | bb |
| 30. | Medical Air | MA | Yellow/ Black | GG | XXVII | bb |
| 31. | Medical Vacuum | MV | White/ Black | GG | XXVII | L |
| 32. | Laboratory Air | LA | Yellow/ White | GG | XXVII | bb |
| 33. | Laboratory Vacuum | LV | White/ Black | Q | XVIII | L |
| 34. | Medical Gas Evacuation | WAGD/EVAC | Violet/ White | GG | XXVII | L |
| 35. | Animal Vacuum | AV | White/ Black | GG[12] | XXVII | L |
| 36. | Animal Oxygen | AO2 | Green/ White | GG | XXVII | bb |
| 37. | Acetylene/Acetylene Mixtures | $C_2H_2$ | Yellow | II | XXVIII | k |
| 38. | Special Lab Gasses/High Purity Gasses | | Yellow | RR | XXXVIII | ii |
| 39. | Fuel Supply | FOS/FOR | Yellow | | | |
| a. | 62 mm (2.5 in.) and larger | | | II | XXIX | r |

| Pipe Service, Service Designation, Color Code, Material, Fittings and Joints | | | | | | |
|---|---|---|---|---|---|---|
| Line item | Pipe Service (Note 22) | Service Designation Abbreviation | Color Code | Pipe Material Type | Pipe Fitting Type | Pipe Joint Type |
| b. | 50 mm (2 in.) and smaller | | | II | XXVIII | r |
| 40. | Fuel Oil Vent | FOV | Yellow | II | XXIX | r |
| 41. | Natural Gas | G, under 14kPa (2 psi)<br><br>G2, 14 kPa (2 psi)<br><br>G5, 35 kPa (5 psi) | Yellow | | | |
| a. | Aboveground - 14 kPa (2 psi) and less, size 62 mm (2.5 in.) and smaller | | | II[13] | XXVIII | k |
| b. | Aboveground - 14 kPa (2 psi) and less, size 75 mm (3 in.) and larger | | | II[13] | XXIX | r |
| c. | Aboveground - Above 14 kPa (2 psi), all sizes. | | | II[13] | XXIX | r |
| d. | Underground – outside building | | | NN | XXX | hh |
| e. | Exposed fume hood and laboratory Equipment connections | | | II/OO | XXVIII, XXXI | k/dd |
| 42. | Compressed Air/ Control Air[14] | CA, A120, A100, etc | Blue | Q,T,GG HH | XVIII XXVII | L |
| 43. | Dental Vacuum (Aboveground and underground) | DV | White/ Black | Q K | VIII XIV | e f |
| 44. | Refrigerant Piping | RS/RL | Yellow | | | |
| a. | 62 mm (2.5 in.) and larger | | | II | XXIX | R |
| b. | 50 mm (2 in.) and smaller | | | S | XVIII | ff |
| 45. | Refrigerant Relief | RR | Yellow | II | XXIX | r |
| 46. | Generator Exhaust | | n/a | KK | XXIX | r |
| 47. | Clean steam (except USP Pure Steam) | CS | Yellow | M[16] | XV | r |
| 48. | Cryogenic Systems | | | Note 18 | Note 18 | Note 18 |

*Notes:*

1. *Hub may be cut off below ground and hub-less pipe extended above grade for appropriate transition adapter to aboveground material. (This allows pipe to fit in standard walls and chases.)*
2. *Piping shall be avoided above food preparation areas, food storage rooms, and surgical areas. Where otherwise unavoidable, such piping and fittings shall be double-contained by polypropylene double containment of minimum SDR-33 thickness, and sealed capable of 35 kPa (5 psi). Storm and cold condensate carrier lines shall be insulated.*
3. *Do not use this material for waste lines from soda fountains.*

4. *Copper pipe not acceptable for drainage from urinals blood analyzers, or any corrosive wastes. May be used for trap arms from sinks in kitchens, but not acceptable for waste piping from floor drains or floor sinks that are located in kitchens*
5. *Glass shall not be used for vents through roof. Avoid use of glass for photo processing waste floor drain traps as it could allow light transfer into space.*
6. *No joints permitted below building slab.*
7. *Use joint Type "J" for aboveground (non-buried) applications.*
8. *Grooved joints in domestic/lab/non-potable and chilled pressurized water systems shall only be permitted where the joints are located to be readily accessible or provided with service access, and where a minor leak or seepage would not cause significant damage or loss.*
9. *PVDF should not be used for highly caustic wastes. Acceptable for drainage from cagewash equipment where equipment is fitted with internal pH neutralization.*
10. *Concealed waste from animal holding rooms may be solid wall PVC instead of polypropylene lab waste where the waste is treated as part of the general sanitary DWV system and pH neutralization is not required. Where connected to the lab waste system, any NIH approved material for lab waste systems may be used for areas not subject to mechanical damage. The use of such material provides increased resistance to the concentrated urines, cleaners, and disinfectants. The term "concealed" in this context is intended to refer to piping that is not exposed to potential mechanical damage from animals or cages. Piping exposed to potential mechanical damage must be protected or be of approved durable materials such as ductile iron, cast iron, stainless steel, or high silicon iron as appropriate for the application and needed corrosion resistance.*
11. *Provide continuous schedule 40 PVC sleeve, with minimum 100 mm (4 in.) concrete encasement and metallic warning tape at sleeve and again halfway between initial backfill and finished grade.*
12. *The use of unclean pipe and fittings shall be permitted only where variance is granted in response to an acceptable plan presented by the contractor to prevent possible misuse of the vacuum system materials on a medical/clean gas system.*
13. *Pipe and fittings shall be provided with protective coating for installation in corrosive environments and exterior installations, Epoxy coating for interior applications, urethane coating for exterior applications exposed to sunlight.*
14. *Select as required based on system application, pressure, and cleanliness requirements.*
15. *Where caulked joints are utilized, interior of piping mains shall be inspected by video camera and demonstrate that joints have been properly made without resultant joint packing material extending into piping interior prior to concealment or backfill.*
16. *Completed system process contact surfaces shall be electropolished.*
17. *Type L wall thickness tubing may be used in lieu of Type K for copper piping for above ground domestic and lab water piping installations serving extramural projects located outside of the metropolitan Washington DC area only if prevailing practice and water supply conditions are compatible with Type L copper tubing. Domestic and lab water piping installation at NIH Bethesda Campus and Poolesville facilities shall utilize Type K tubing as indicated in table B.8.*
18. *Cryogenic piping systems shall be stainless steel vacuum jacketed, passive or dynamic type. Refer to high containment section for special requirements for BSL-3 and BSL-4.*
19. *Flanged joints not permitted for underground applications.*
20. *Refer to Biocontainment chapter for waste and vent piping systems serving BSL-4 high containment or other areas where effluent decontamination systems are required by biosafety analysis for the program. Special provisions for piping materials do not generally apply to BSL-3 laboratories.*
21. *Purified water systems shall be identified with nomenclature specific to the system water quality. For example, HPWS/HPWR- ASTM 2b may be used to designate the High Purity Water Supply/Return of ASTM Type 2, bacteria grade B Water Quality. If following CLSI (formerly NCCLS), designations such as CLRW (S) (R) may be used for supply and return in accordance with the standards' nomenclature. Generic designation of water systems as RO or DI is not acceptable, and should never be used for water qualities operating at Type/Grade II or better. Where multiple systems of similar water quality are required in the same facility, additional identification specific to the application may be required. The design water quality of each system shall be clearly indicated in the project Basis of Design and Project Record Documents.*
22. *In renovation of existing facilities where connections are made to existing piping, it is preferable that the new piping be similar to the existing piping materials in as much as possible so long as the materials and joint methods are in conformance with the requirements of this table.*

| Pipe Material Type Designation and Material Specifications | |
|---|---|
| Material Type Designation | Pipe Material Specifications |
| A | Cast iron hub and spigot pipe, service weight, ASTM A74. |
| B | Cast iron hub and spigot, extra heavy weight, ASTM A74. |
| C | Ductile iron, ASTM A-746, not less than Special Thickness Class “52” with AWWA C116 fusion bonded epoxy or 40 mil ceramic epoxy interior lining. |
| D | Cast iron hub-less pipe, ASTM A74, ASTM A888, CISPI 301. |
| E | High silicon iron pipe, ASTM A518, ASTM A861. |
| F | Stainless steel waste pipe, Type 316, ANSI A112.3.1. |
| G | Stainless steel waste pipe, Type 304, ANSI A112.3.1 |
| H | Polypropylene pipe, ASTM F1412, ASTM D4101, ASTM D618, ASTM D2447 Schedule 40 or 80. |
| I | Flame retardant polypropylene pipe, ASTM F1412, ASTM D4101, ASTM D618, ASTM D635, ASTM D2843, ASTM D2447, Schedule 40 |
| J | Borosilicate glass pipe, ASTM C1053. |
| K | Polyvinyl chloride pipe, ASTM D1785 or ASTM D2665 dual stamped Schedule 40. Cellular core or foam core not accepted. |
| L | Polyvinyl chloride pipe, ASTM D1785 Schedule 80. |
| M | Type 304L or Type 316L stainless steel pipe, Schedule 40, ASTM A312 seamless. Low carbon not required for applications where welding is not mandated. |
| N | Reserved (Not Used) |
| O | Ductile iron pipe, ASTM A746, not less than Special Thickness Class 52, with AWWA/ANSI C104 cement mortar interior lining with sealcoat. |
| P | Porous concrete pipe, AASHTO M-176. |
| Q | Seamless copper tube, ASTM B88, Type L Hard. |
| R | Seamless copper tube, ASTM B88, Type L Soft. |
| S | Seamless copper tube, ASTM B88, ASTM B280 type ACR, Type L or Type K |
| T | Seamless copper tube, ASTM B88, Type K Hard. |
| U | Seamless copper tube, ASTM B88, Type K Soft. |
| V | Ductile iron pipe, cement lined, ANSI/AWWA C150, C151, AWWA C104, ANSI A21.4, minimum special thickness class 52 or minimum pressure class 250. |
| W | Ductile iron flanged pipe, cement lined, ANSI/AWWA C150, C151, AWWA C104, ANSI |

| Pipe Material Type Designation and Material Specifications | |
|---|---|
| Material Type Designation | Pipe Material Specifications |
| | A21.4, AWWA C115, minimum special thickness class 52 or minimum pressure class 250, suitable for operation to 90°C (190°F), piping for hot water shall not have sealcoat. |
| X | Ductile iron pipe, cement lined, ANSI/AWWA C150, C151, AWWA C104, ANSI A21.4, minimum special thickness class 52 or minimum pressure class 250, AWWA C105 8-mil polyethylene encasement. |
| Y | Stainless steel pipe, Type 316, Schedule 10, 20, or Schedule 40, AWWA C220, ASTM A312, ASTM A778. Minimum 0.61 m/s velocity for any stainless steel water piping system. Piping insulation must be specified as chloride-free. |
| Z | Brass pipe and nipples ASTM B43, ANSI B687 seamless regular or extra-strong, ASTM B456 chrome plating for finished locations. |
| AA | Galvanized steel pipe, ASTM A53 or ASTM A106, Grade B, Type S or Type E, ASTM A123/A153 Schedule 40. |
| BB | CPVC pipe, ASTM F441, Class 23447B, Type IV, Grade 1, Schedule 40 or Schedule 80. |
| CC | Stainless steel sanitary tube, ASTM A270, ASTM A450, ANSI B36.19M, Schedule 10 electropolished 130 to 150 grit sanitary interior. |
| DD | Un-pigmented polypropylene pipe, ASTM D4101, ASTM D2837, SDR 11 or schedule 80, individual cap, sealed bag or ends. |
| EE | As required by program requirements and required water quality. |
| FF | PVC, polypropylene, cross-linked polyethylene (PEX) or stainless steel tubing as required by application and compatible with required fire/smoke criteria. |
| GG | ASTM B819 Copper tube, cleaned and degreased for oxygen service, Type L hard, factory nitrogen charged and ends capped. Any piping contaminated or not under nitrogen charge at time of installation not accepted. Type ACR not acceptable due to sizing differences. |
| HH | ASTM B819 Copper tube, cleaned and degreased for oxygen service, Type K hard, factory nitrogen charged and ends capped. Any piping contaminated or not under nitrogen charge at time of installation not accepted. Type ACR not accepted due to sizing differences. Provide continuous sleeve and encasement for underground medical gas piping as directed under Piping Section. |
| II | Carbon steel pipe, ASTM A53 or A106, Grade B, Type S seamless or Type E electric resistance welded, Schedule 40. |
| JJ | Carbon steel pipe, ASTM A53 or A106 Grade B, Type S seamless Schedule 80, XS or extra heavy wall. |
| KK | Carbon steel pipe, ASTM A106 Grade B, Type S seamless, Schedule 40. . |
| LL | Carbon steel pipe, ASTM A106, Grade B, Type S seamless, Schedule 80, XS, or extra |

| Pipe Material Type Designation and Material Specifications | |
|---|---|
| Material Type Designation | Pipe Material Specifications |
| | heavy wall. |
| MM | Carbon steel pipe, API-5L Type DSAW, Grade B, 0.5 inch wall thickness double submerged arc-welded longitudinal seam. |
| NN | Polyethylene fuel gas pipe and tubing, PE-2406 or PE-3408 as appropriate, minimum thickness of SDR-11, ASTM D2513, cell classification of PE213363 or PE334464, minimum hydrostatic design basis of 6890 kPa (1,000 psi) at 22.8°C (73°F) per ASTM D2837. Comply with stress crack and test provisions of ISO 4437, ISO 9080, and Part 192 of Title 49 CFR. |
| OO | Steel fuel gas tubing, ASTM A539 electric resistance welded. |
| PP | Schedule 40 PVDF (Polyvinylidene Fluoride), ASTM F1673, ASTM D3222 |
| QQ | Perforated PVC, ASTM D2729, ASTM D3034, ASTM D2665 |
| RR | Type 316L Stainless steel tubing, generally ASTM A213, ASTM A269 with hardness not to exceed Rb 80. Interior surface finish, cleanliness and pipe wall selected for application. Packaging, joint precautions, cleaning and purging as appropriate to required service purity. |

| Pipe Fitting Type and Fitting Specifications | |
|---|---|
| Fitting Type Designation | Pipe Fitting Specifications |
| I | Service cast iron hub and spigot, ASTM A74. |
| II | Extra heavy cast iron hub and spigot, ASTM A74. |
| III | Ductile iron, ANSI/AWWA C110, ASTM A746, minimum Special Thickness Class 52, with AWWA C116 fusion bonded epoxy or 40 mil ceramic epoxy, interior lining and fitting patterns consistent with drainage systems. |
| IV | Cast iron hub-less fittings, CISPI 301. |
| V | High silicon iron drainage pattern fittings. |
| VI | Type 316 stainless steel, drainage pattern, ANSI A112.3.1. |
| VII | Type 304 stainless steel, drainage pattern, ANSI A112.3.1. |
| VIII | Wrought copper and bronze drainage pattern fittings, ANSI B16.23 or ANSI B16.29. |
| IX | Cast iron, 'Durham' drainage pattern, ASTM A126, ANSI B16.12, ASTM A153. |
| X | Polypropylene drainage pattern, ASTM F1412, ASTM D4101, ASTM D618, ASTM D2447, ASTM D3311. |
| XI | Borosilicate glass drainage pattern, ASTM C1053. |
| XII | Flame-retardant polypropylene drainage pattern, ASTM F1412, ASTM D4101, ASTM D618, ASTM D2843, ASTM D635, ASTM D2447, and ASTM D3311. |
| XIII | Chemically resistant compatible with system pipe material and application. |
| XIV | Polyvinyl chloride, drainage pattern, ASTM D2665 ASTM D3311. |
| XV | Type 304L or 316L stainless steel to match piping system. ASTM A403 Grade WP Class S or W. |
| XVI | Ductile iron, ANSI/AWWA C110, minimum Special Thickness Class 52 with ANSI/AWW C104 cement mortar lining and sealcoat, drainage pattern fittings, ASTM A746. |
| XVII | Porous concrete drainage fittings, ASTM C654, AASHTO M176. |
| XVIII | Wrought copper solder cup type fittings, ANSI/ASME B16.22 or B16.18. |
| XIX | Ductile iron cement lined, ANSI/AWWA C110, or C153, AWWA C104/ANSI A21.4, minimum special thickness Class 52 or minimum pressure class 250 |
| XX | Flanged ductile iron cement lined, ANSI/AWWA C110, or C153, AWWA C115, AWWA C104/ANSI A21.4, minimum special thickness class 52 or minimum pressure class 250. Lining applied to pipe and fittings for hot water service shall not have seal coat. |
| XXI | Ductile iron cement lined ANSI/AWWA C110, or C153, AWWA C104/ANSI A21.4 minimum special thickness Class 52 or minimum pressure class 250, all materials NSF-61 compliant, |

| Pipe Fitting Type and Fitting Specifications | |
|---|---|
| Fitting Type Designation | Pipe Fitting Specifications |
| | AWWA C105 8-mil polyethylene encasement. |
| XXII | Stainless steel mechanical groove joint, Type 316, Schedule 10, 20, or Schedule 40, ASTM A403, ASTM A774, ASTM A312, ASTM A778. |
| XXIII | Cast bronze pressure threaded pressure fittings, ANSI B16.5. Provide with ASTM B456 chrome plating for finished locations. |
| XXIV | CPVC Schedule 40 or Schedule 80, ASTM F439 Type IV, Grade I socket type, Schedule 80 threaded type. |
| XXV | Stainless steel sanitary fitting, Type 316, Schedule 10, electropolished, sanitary interior 130 to 150 grit finish, ASTM A270, ASTM A450, ANSI B36.19M. |
| XXVI | Natural polypropylene, un-pigmented ASTM D4101, furnished in sealed nitrogen-charged bag. Socket fusion style or IR butt fusion style without use of embedded coils. |
| XXVII | Wrought copper solder cup type fittings, ANSI/ASME B16.22, factory cleaned and degreased for oxygen service. Factory nitrogen charged and bagged maximum 20 fittings per bag. |
| XXVIII | Malleable iron threaded fittings, ANSI B16.3. Fittings shall be 57 kg (125 lb. minimum) for pressures less than 517 kPa (75 PSI) and 136 kg (300 lb.) for over 517 kPa (75 PSI). Steam condensate shall be 136 kg (300 lb.) for all pressures. |
| XXIX | Steel butt weld fittings, ANSI B16.9, ASTM A234, Grade WPB, long turn ells, ANSI B16.5 weld-neck (preferred) or slip-on forged carbon steel ANSI B16.5 flanges, Weld-o-lets and thread-o-lets permitted if branch at least 2 pipe sizes smaller than main, fittings at least wall thickness to match pipe. 136 kg (Class 300) flanges required for steam pressures above 100 kPa (15 PSI), 68 kg (Class 150) below 100 kPa. |
| XXX | Comply with requirement for pipe designation NN. ASTM D2683 socket fusion or ASTM D3261 butt fusion type. |
| XXXI | Swagelock type NFPA-54 compliant fuel gas fitting to match piping application. Use only for final equipment connection at fume hoods and similar equipment. |
| XXXII | As required by program requirements and required water quality. |
| XXXIII | Malleable iron grooved fittings and couplings, ASTM A47. |
| XXXIV | Cast iron threaded fittings, ANSI B16.4. Fittings shall be 57 kg (125 lb. minimum) for less than 517 kPa (75 PSI) and 113 kg (250 lb. minimum) for pressures above 517 kPa (75 PSI). Steam condensate shall be 113 kg (250 lb. minimum) for all pressures. |
| XXXV | Steel socket weld fittings, ANSI B16.11, wall thickness to match pipe. |
| XXXVI | Galvanized steel grooved fittings and couplings, ASTM A47M or ASTM A536. Note: Cut-groove type only. Roll-grooving not permitted for galvanized or lined piping. |

| Pipe Fitting Type and Fitting Specifications | |
|---|---|
| Fitting Type Designation | Pipe Fitting Specifications |
| XXXVII | Schedule 40 drainage pattern PVDF, ASTM F1673, ASTM D3222, ASTM F1412 |
| XXXVIII | Type 316L stainless steel to match tubing system. Exposed fittings may be double-ferrule type mechanical joint where compatible with service application. Packaging, joint precautions, cleaning and purging as appropriate to required service purity. |

| Pipe Joint Type Designation and Joint Specifications | |
|---|---|
| Joint Type Designation | Pipe Joint Specifications |
| a | Pre-molded neoprene compression gasket to ASTM C564. |
| b | ASTM C111 compression gasketed (Tyton) joints. Provide with restraining gasket where required due to thrust loads. |
| c | Heavy-duty shielded couplings meeting ASTM 1540 or FM 1680, with stainless steel shield and neoprene gasket. Couplings shall be a minimum of 4-band type, unless FM1680 approved otherwise. |
| d | CISPI 310 stainless steel shielded neoprene coupling. |
| e | ASTM B32 lead-free soldered joints, noncorrosive flux. |
| f | Solvent cemented ASTM 2564 NSF listed cement and ASTM F656 NSF listed primer to IAPMO installation standard 9-95. "Hot" cements or wet-type fast dry cements shall not be utilized. Solvent cement joints only in dry ambient conditions and cement type appropriate for ambient temperature and pipe size. |
| g | Hub and spigot caulked type with acid resistant packing and molten lead in accordance with manufacturer requirements. |
| h | Mechanical joint type with Teflon seal, neoprene outer gasket, and stainless steel shield as provided by pipe and fitting manufacturer. |
| i | Elastomeric sealed socket type joint by pipe and fitting manufacturer. Provide with joint clamps for all non-buried applications. NBR (Nitrile) or Viton (FPM) gasket as appropriate. Typically NBR for grease waste, EPDM for general sanitary, FPM for high temperature or corrosive applications. EPDM not permitted for applications exposed to grease/oils. |
| j | ASTM C111 neoprene gasketed lock-ring type restrained joints by pipe and fitting manufacturer. |
| k | Threaded using American Standard for Pipe Threads, ANSI B2.1 with thread sealant or Teflon tape material especially listed compatible with system contents, pipe materials, and operating conditions. |
| L | BCuP 2, 3, 4, or 5 brazed joints. |
| m | ASTM D2657 socket fusion to practice method 1. |
| n | Mechanical joint type with Teflon seal, neoprene gasket, and stainless steel shield over bead to bead or bead to plain end where required. |
| o | ASTM F1290 electrofusion with stainless steel coil. |
| p | ASTM D2657 butt fusion method. |
| q | To match pipe material. |
| r | Butt weld to ANSI B31.1 and MCAA Part VII, Standard Procedure Specification Parts 1 & 2 |

| Pipe Joint Type Designation and Joint Specifications | |
|---|---|
| Joint Type Designation | Pipe Joint Specifications |
| s | Tongue and groove, mortar sealed. |
| t | AWWA C111 mechanical joint with restraint fitting/retainer gland or approved neoprene gasketed restraint push on joint. Full restraint and thrust blocks. All bolts, nuts, and accessories AWWA compliant grade and type, Cor-Blue fluorocarbon coated low alloy high strength steel bolts/ nuts. Restraint shall be UL and FM listed, comply with UL standard 194, ductile iron construction and shall not be flow-direction dependent. |
| u | AWWA cut groove method with NSF-61 listed gasket. |
| v | AWWA C110 or C115 flanged with AWWA C111 special gasket type EPDM for water systems, with not less than ASTM A307 grade B low carbon bolts. |
| w | ASTM B32 lead-free solder with ASTM B813 water soluble flux. |
| x | Mechanical groove joint, roll-groove method, with galvanized steel or stainless steel coupling, NSF-61 listed EPDM gasket. |
| y | ASTM D2846, F-493 NSF listed solvent cemented joints with ASTM F656 NSF listed primer. |
| z | Sanitary butt weld method such as orbital welding or sanitary mechanical joint (clean joint), as required based on fluid quality. |
| aa | As required by program requirements and required water quality. Type III waters shall be IR butt fusion, welded, or socket fusion without use of embedded coils. Type II waters may be IR butt fusion, welded, or approved crevice free fusion system. |
| bb | BCuP 2, 3, 4, or 5 brazed joints without flux to NFPA 99 Level 1 system standards and ASSE series 6000 installation procedure, including clean, dry nitrogen purge. |
| cc | ASTM D2657 socket fusion or butt fusion only. Mechanical joints shall not be used. |
| dd | Swagelock fitting only at final connection to equipment. |
| ee | Grooved joint, ASTM A536 Ductile Iron coupling, ASTM A183, ASTM B633 and ASTM A183 bolts and nuts with minimum tensile strength of 110,000 psi, ASTM D2000 rubber gaskets selected for service application. Roll groove method only, except that cut groove type shall be utilized for applications where piping has interior lining or interior coating, including galvanized systems. |
| ff | AWS A5.8 Bag-5 with AWS Type 3 flux, except Type BCuP 5 or BCuP 6 may be used for copper to copper joints. |
| gg | Methods and materials for wet taps, where permitted by the NIH, shall be submitted for approval by the A/E. Submittals shall include documentation on the products to be used with complete instructions and procedures to ensure successful wet taps. |
| hh | ASTM D2657 heat socket fusion or heat butt fusion only. Mechanical joints not permitted. |

| Pipe Joint Type Designation and Joint Specifications | |
|---|---|
| Joint Type Designation | Pipe Joint Specifications |
| ii | Orbital weld for non-accessible locations. Exposed joints may be double-ferrule mechanical joint where compatible with service application. Joint precautions, cleaning and purging as appropriate to required service purity. |

| Recommendations for Steam Trap Applications | | | | | |
|---|---|---|---|---|---|
| Application (1) | Steam Trap sizing Safety factor | Steam Trap type (5) | | | |
| | | Float / Thermostatic | Balanced Pressure thermostatic | Disc Thermo-dynamic | Inverted Bucket |
| Kitchen Warming Equipment (2) | 2 | X | | | |
| Laboratory Equipment (3) | 2 | X | | | |
| - Autoclaves and sterilizers, medium pressure | 2 | | | | X |
| Heating Equipment | | | | | |
| - Shell and tube heat exchangers | 2 | X | | | |
| - Steam coils (4) | 4 | X | | | |
| - Cabinet and unit heaters (6) | 3 | X | | | |
| - Radiant panels and strips | 2 | X | | | |
| - Radiators and convection cabinet heaters | 2 | | X | | |
| - Humidifiers | 2 | | X | | |
| - Water heaters | 2 | X | | | |
| - Water heaters – medium pressure | 2 | | | | X |
| Steam Piping | | | | | |
| - Horizontal runs and low point drains | 2 | X | | | |
| - Horizontal runs and low point drains - medium pressure and high pressure | 2 | | | X | |
| - Flash tanks | 2 | X | | | |
| - Flash tanks, medium pressure and high pressure | 2 | | | X | |

*Notes:*

*(1) Unless noted otherwise, all equipment in this table is served with low pressure steam*

*(2) Steam traps associated with kitchen warming equipment shall be as per this table unless noted otherwise by the kitchen equipment manufacturer.*

*(3) Steam traps associated with laboratory equipment shall be as per this table unless noted otherwise by the laboratory equipment manufacturer*

*(4) Top of traps serving steam coils shall be installed a minimum of 300 mm (12-in) below the bottom of the coil.*

*(5) Trap bypass valves shall not be installed; if redundancy is required or capacity dictates dual traps shall be installed.*

(6) Equipment with modulating control valve

# Section 6-4: Thermal Insulation Systems



## 6-4-00 Design Requirements

### A. General Insulation Requirements:

Insulation systems shall be specified to meet industry standards and, as a minimum, include the following:

- Insulation materials approved for use in NIH buildings shall have a fire hazard rating not to exceed 25 for flame spread and 50 for smoke developed. All materials shall be factory tested as an assembly. Fire ratings shall be determined by the standard method of testing for surface-burning characteristics of building materials, ASTM E84 or NFPA Standard 255.
- Insulation approved for use shall have a UL label or a certified test report from an approved testing laboratory.
- Insulation installation shall be in accordance with the National Commercial & Industrial Insulation standards published by the Midwest Insulation Contractors Association
- All adhesives, sealers, vapor barrier coatings, etc. used in conjunction with insulation shall be compatible with the material to which they are applied. Any cement, sealer or coating used shall be resistant to vermin and mold.
- All insulation surfaces shall be durable and, where exposed, protected from damage due to maintenance operations, vandalism, weather, and normal wear and tear.
- Insulation exposed to weather shall be covered with 0.41 mm (0.016 in.) aluminum jackets.
- Insulation shall be continuous at all hangers, hanger rods, supports, sleeves, and openings. Vapor seals shall be provided for all cold surfaces and shall be continuous. Where supports occur below the insulation surface, the thickness shall be maintained over the support and extend sufficiently beyond the support to prevent condensation. Insulation shall be sealed at all termination points.
- All insulation shall be arranged to permit expansion and contraction of systems without causing damage to the insulation or surface.
- High-density pipe saddles or welded pipe standoffs shall be provided at all points of pipe support.

- Valves shall be insulated up to and including bonnets, except for cold water valves, which shall be insulated over packing nuts in a manner to permit removal for adjustment and repacking.
- On ductwork or equipment, accessories shall be provided as required to prevent distortion and sagging of insulation. Welded pins, adhesive clips, and wire ties shall be provided as recommended by the manufacturers and SMACNA.
- Duct and equipment insulation shall cover all standing seams and metal surfaces with full-thickness insulation.
- Preformed insulation systems shall be provided at pumps, valves, strainers, and access doors.
- Valves and specialties that are 75 mm (3 in.) and larger shall be insulated with custom-made canvas jackets with straps and buckles to allow frequent removal and reinstallation without damaging the jackets.
- Cold-water pumps shall be insulated with removable and replaceable square or rectangular covers consisting of full 1.25 mm (50 mils) thick aluminum metal jackets, reinforced at corners and edges and lined with insulation. Pumps with split casings shall be constructed with insulated housing in two or more sections with the upper section removable for access to the casing. Lube fittings and drain valves shall extend outside insulated covers.
- Insulation in containment spaces must be sealed at each end and must have a smooth and cleanable jacket.
- Metallic components used for the installation of insulation systems shall be suitable for the intended environment and shall not corrode.
- The A/E shall include in the design documents instructions to the constructor not to insulate the specified systems until all necessary tests have been conducted for each component and insulated surfaces have been thoroughly cleaned and are in a dry state.

## B. System not requiring insulation:

Insulation shall be omitted on the following systems and items:

- Brass or copper pipe specified to be chrome plated (typically applies to toilet rooms).
- Steam traps, steam powered pumps, steam condensate pumps, and concealed relief piping from safety valves.
- All fire protection piping and components.
- All fuel oil piping and components.
- Exposed ducts in air-conditioned spaces if duct is not prone to condensation.
- ASME stamps.
- Access plates of fan housings.
- Cleanouts or hand-holds.

- Manufacturer's nameplates.
- Vibration-isolating connections.

## 6-4-10 Design Guidance

### A. Insulation Material for Piping:

Exhibit X6-4-A defines the minimum insulation standards for NIH projects and is intended as a guide for the services listed and other similar services not indicated. The A/E shall select the most suitable product for each individual service.

### B. Piping Insulation Thickness:

The A/E shall select the piping insulation thickness per ASHRAE 90.1-2004 or Exhibit X6-4-B, whichever is more stringent.

### C. Cold Equipment Insulation:

The A/E shall select cold equipment insulation thickness per ASHRAE 90.1-2004 or the table below, whichever more stringent.

| Insulation Thickness for Cold Equipment | | |
|---|---|---|
| System Temperature of Cold Equipment | Material (Note 1) | Insulation Thickness mm (in.) |
| 2°C (35°F) to 16°C (60°F) | Cellular Glass | 38 (1.5) |
| | Flexible Elastomeric Cellular | 32 (1.25) |
| -18°C (0°F) to 1°C (34°F) | Cellular Glass | 75 (3) |
| -34°C (-29°F) to -17°C (-1°F) | Cellular Glass | 88 (3.5) |

*Notes:*

*1. Other insulation materials may be acceptable. The A/E shall submit a variance request for approval.*

### D. Hot Equipment Insulation:

The A/E shall select hot equipment insulation thickness per ASHRAE 90.1-2004 or the table below, whichever is more stringent.

| Insulation Thickness for Hot Equipment | | |
|---|---|---|
| Pressure and Temperature range for Equipment Handling Steam or Other Media | Material (Note 1) | Insulation Thickness mm (in.) |
| To 138 kPa (20 psi), 126°C (259°F) | Rigid Mineral Fiber | 50 (2) |
| | Cellular Glass | 75 (3) |
| 145 kPa (21 psi), 126°C (260°F) to 1379 kPa (200 psi), 198°C (388°F) | Rigid Mineral Fiber | 75 (3) |
| | Calcium Silicate / Perlite | 100 (4) |
| | Cellular Glass | 100 (4) |

*Notes:*

*1. Other insulation materials may be acceptable. The A/E shall submit a variance request for approval.*

## E. Supply and Outdoor Air Ductwork Insulation:

The A/E shall select the ductwork insulation thickness per ASHRAE 90.1-2004 or the table below, whichever is more stringent.

| Insulation Thickness and Density for Supply and Outdoor Air Ductwork | | | |
|---|---|---|---|
| Insulation Type | Indoors & Concealed | Indoors & Exposed | Outdoors & Exposed to Weather |
| Blanket - Flexible mineral fiber / Fiber glass - ASTM C 1290, Type III, FSK faced | 50 mm (2 in.) thick 24 kg/m$^3$ (1.50lb/ft$^3$) | | |
| Board - Rigid mineral fiber / Fiber glass - ASTM C 612, Type IA, and IB, FSK faced | 40 mm (1.5 in.) thick 48 kg/m$^3$ (3lb/ft$^3$) | 50 mm (2 in.) thick 48 kg/m$^3$ (3lb/ft$^3$) | 75 mm (3 in.) thick 48 kg/m$^3$ (3lb/ft$^3$) |

*Notes:*

*1. Other insulation materials may be acceptable. The A/E shall submit a variance request for approval.*

| Pipe Insulation Material and Specifications | | | | | | |
|---|---|---|---|---|---|---|
| Service | Material (1, 6, 7, 8) | Specification | Type | Class | Minimum Jacket (2, 3) | Vapor Barrier Required |
| Chilled Water Supply, Return and Dual Temperature Piping Nominal 4.44°C (40°F) | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C 547 | 1 | 1 | ASJ | Yes |
| | Cellular Glass | ASTM C 552 | II | 2 | ASJ / Fabric reinforced or metal | No |
| Heating Hot Water Supply & Return Max 121°C (250°F) | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C 547 | I | 1 | ASJ | No |
| Cold Domestic, Non-potable, and Laboratory Water Piping | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C547 | I | 1 | Factory Applied, ASJ | Yes |
| Hot Domestic, Non-Potable, Tempered, and Hot Water Circulation Pip-ing, Max 93°C (200°F) | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C547 | I | 1 | Factory Applied, ASJ | No |
| Refrigerant Suction Piping Nominal 1.67°C (35°F) | Flex Elastomeric Cell'r | ASTM C 534 | I | | None | No |
| Compressed Air Discharge | Mineral Fiber (Fiber glass and Mineral Wool) | ASTM C 547 | I | 1 | ASJ | No |
| Sanitary and Clear Water Waste Lines and drain receptors receiving cold condensate, ice machine, and similar wastes from drain inlet source to vertic-al waste stack or point of adequate temperature dilution | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C547 | I | 1 | ASJ | Yes |
| | Flex Elastomeric Cell'r | ASTM C 534 | I | | None | No |
| Aboveground horizontal and vertical Storm Drain Piping and drain receptor. | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C547 | I | 1 | ASJ | Yes |
| | Flex Elastomeric Cell'r | ASTM C 534 | I | | None | No |
| Aboveground horizontal Overflow Storm Drainage (overflow roof drain) piping and drain receptor. Ver-tical piping need not be | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C547 | I | 1 | ASJ | Yes |
| | Flex Elastomeric Cell'r | ASTM C 534 | I | | None | No |

| Pipe Insulation Material and Specifications | | | | | | |
|---|---|---|---|---|---|---|
| Service | Material (1, 6, 7, 8) | Specification | Type | Class | Minimum Jacket (2, 3) | Vapor Barrier Required |
| insulated. | | | | | | |
| A/C and Cold Condensate Drain Located Inside Bldg. | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C547 | I | 1 | Factory Applied ASJ | Yes |
| | Flex Elastomeric Cell'r | ASTM C 534 | I | | None | No |
| Medium Temperature Hot Water, Steam and Condensate 94°C (201°F) to 176°C (349°F) | Mineral Fiber (Fiberglass and Mineral Wool) | ASTM C 547 | I | 1 | ASJ | No |
| High Temperature Hot Water & Steam 177°C (350°F) and higher | Mineral Fiber (Mineral Wool On-ly) | ASTM C 547 | II | 1 | Metal or ASJ de-pendent on tem-perature | No |
| | Calcium Silicate (4) | ASTM C 533 | I, II | | Fabric reinforced, 8 oz. min. over ASJ | No |
| | Perlite | ASTM C 610 | I | | Fabric reinforced, 8 oz. min. over ASJ | No |
| Diesel Engine Exhaust | Calcium Silicate | ASTM C 533 | I, II | | Fabric reinforced, 8 oz. min. over ASJ | No |
| | Cellular Glass | ASTM C 552 | II | 2 | ASJ / Fabric reinforced or metal | No |

*Notes:*

1. *Other insulation material may be acceptable. The A/E shall submit substitutions for approval. Materials shall comply with required flame/smoke spread requirements for the installed location.*
2. *Piping exposed to weather, located in Parking Garages, exposed in materials handling or transport areas less than 2.5 m (8-ft.) above the floor, or located where otherwise susceptible to damage or abuse shall be insulated and jacketed as specified above and covered with a 0.41 mm (0.016 in.) aluminum or stainless steel jacket in conformance with ASTM B209. Provide with heat-bonded polyethylene and kraft paper vapor barrier, 0.075 mm (0.03 in.) thick for outdoor applications, 0.025 mm (0.01 in.) minimum for in-door applications.*

3. *Jacket indicated is for typical indoor building service. Piping located in mechanical rooms less than 2.5 m (8-ft.) above the floor shall be provided with (0.75 mm (30 mill) thick PVC, min. 8 oz. canvas over ASJ, or suitable metal (aluminum or stainless steel) jacket. Steam PRVs and general valves of sizes 6-inches and larger shall be provided with an approved industrial grade removable thermal insulation jacket system suitable for system application*
4. *Perlite conforming to ASTM C610 may also be utilized. Calcium silicate and Perlite typically for mechanical/ utility areas and not recommended for areas sensitive to potential dust.*
5. *Insulation Inserts: ASTM C1126 closed cell phenolic foam blocks, or high density, high compressive strength insulation, certified chloride free per ASTM C795 and ASTM C-692 if applied with stainless steel piping systems. High temperature systems typically use calcium silicate.*
6. *Insulation applied to stainless steel piping systems shall be certified chloride-free per ASTM C795 and ASTM C-692.*
7. *Insulation applied in areas subject to excessive moisture shall be moisture resistant and/or fitted with approved sealed jacket. Insulation subject to compressive loads (including areas where piping is likely to be walked or crawled upon) shall be of approved type, suitable for anticipated compressive forces.*
8. *Insulation located in areas considered clean, sterile, or otherwise requiring special cleanliness characteristics shall be certified for use in food processing and clean room areas and submitted for prior approval.*

| Piping Insulation Minimum Thickness | | | | | | |
|---|---|---|---|---|---|---|
| Service | Material (1, 2, 3) | Nominal Pipe Sizes, mm (in.) | | | | |
| | | 13 to19 (0.5 to 0.75) | 25 to 32 (1 to 1.25) | 38 to 75 (1.5 to 3) | 100 to 150 (4 to 6) | 200 (8) and larger |
| Chilled Water - Indoor -Supply & Return Nominal 4°C (40°F) | Cellular Glass | 25 (1) | 38 (1.5) | 50 (2) | 50 (2) | 62 (2.5) |
| | Mineral Fiber Note 4 | 25 (1) | 25 (1) | 38 (1.5) | 38 (1.5) | 38 (1.5) |
| Chilled Water - Outdoor & Ab-oveground - Supply & Return Nominal 4°C (40°F) | Cellular Glass | 25 (1) | 75 (3) | 75 (3) | 75 (3) | 100 (4) |
| | Polyisocya-nurate | 25 (1) | 50 (2) | 50 (2) | 62 (2.5) | 62 (2.5) |
| | Faced Phe-nolic Foam | 25 (1) | 38 (1.5) | 38 (1.5) | 50 (2) | 50 (2) |
| Chilled Water - In tunnels - Supply & Return Nominal 4°C (40°F) | Cellular Glass | 50 (2) | 75 (3) | 75 (3) | 75 (3) | 100 (4) |
| Heating Hot Water – Indoor - Supply & Return, Heated Oil Max 121°C (250°F) | Mineral Fiber Note 4 | 38 (1.5) | 38 (1.5) | 50 (2) | 50 (2) | 88 (3.5) |
| Heating Hot Water - Outdoor - Supply & Return Max 121°C (250°F) | Calcium Silicate | 75 (3) | 75 (3) | 100 (4) | 100 (4) | N/A |
| | Cellular Glass | 75 (3) | 75 (3) | 100 (4) | 100 (4) | N/A |
| Cold Domestic, Non-Potable, Lab Water Piping | Mineral Fiber Note 4 | 25 (1) | 25 (1) | 25 (1) | 25 (1) | 25 (1) |
| Indoor Cold Waste/ Storm/ Clear Water Waste/ Overflow/ Cold Condensate Lines and Drain Receptor. Note 4 | Mineral Fiber Note 4 | 13 (0.5) | 25 (1) | 25 (1) | 25 (1) | 25 (1) |
| | Flex Elas Cell'r | 19 (0.75) | 19 (0.75) | 19 (0.75) | 19 (0.75) | N/A |
| Hot Domestic, Non-Potable, Tempered, and | Mineral Fiber Note 4 | 25 (1) | 25 (1) | 25 (1) | 38 (1.5) | 38 (1.5) |

| Piping Insulation Minimum Thickness | | | | | | |
|---|---|---|---|---|---|---|
| Service | Material (1, 2, 3) | Nominal Pipe Sizes, mm (in.) | | | | |
| | | 13 to19 (0.5 to 0.75) | 25 to 32 (1 to 1.25) | 38 to 75 (1.5 to 3) | 100 to 150 (4 to 6) | 200 (8) and larger |
| Hot Water Circulation piping Max 60°C (140°F) | | | | | | |
| Hot Domestic, Non-Potable, Tempered, and Hot Water Circulation piping 61°C (142°F) to 93°C (200°F) | Mineral Fiber Note 4 | 25 (1) | 25 (1) | 38 (1.5) | 38 (1.5) | 38 (1.5) |
| Refrigerant Suction Piping 1°C (35°F) | Flex Elast Cell'r | 25 (1) | 38 (1.5) | 38 (1.5) | 38 (1.5) | N/A |
| Compressed Air Discharge, Steam, and Condensate Return 94°C (201°F) to 121°C (250°F) | Mineral Fiber Note 4 | 38 (1.5) | 38 (1.5) | 50 (2) | 75 (3) | 88 (3.5) |
| Steam - Indoors 122°C (251°F) to 176°C (349°F) | Mineral Fiber Note 4 | 38 (1.5) | 62 (2.5) | 75 (3) | 100 (4) | 100 (4) |
| Steam - Indoors 177°C (350°F) to 260°C (500°) | Mineral Fiber (Mineral Wool Only) | 62 (2.5) | 75 (3) | 75 (3) | 100 (4) | 100 (4) |
| | Calcium Silicate | N/A | 100 (4) | 100 (4) | 150 (6) | 150 (6) |
| Steam - Outdoor & tunnels | Calcium Silicate | N/A | 100 (4) | 100 (4) | 150 (6) | 150 (6) |
| Diesel Engine Exhaust | Calcium Silicate | N/A | N/A | N/A | 100 (4) | 100 (4) |
| | Cellular Glass | N/A | N/A | N/A | 125 (5) | 150 (6) |

*Notes:*

1. *Fiber Glass VaporWick insulation shall be of same thickness as Cellular Glass.*
2. *Insulation thicknesses are minimum requirements. Comply with current energy conservation and code requirements, and as necessary to protect from unacceptable heat transfer, condensation, freezing, etc.*
3. *13 mm (0.5 in.) thick insulation acceptable for domestic/lab plumbing water drops within interior partitions where necessary to maintain partition wall thickness.*
4. *Mineral Fiber represents Fiberglass and Mineral Wool*
5. See table above for acceptable insulation materials.

# Section 6-5: Noise and Vibration



## 6-5-00 Design Requirements

### A. Required Room Noise Levels:

The table below lists the maximum allowable background NC noise levels for a variety of spaces. NC levels are based on rooms not being occupied and with all user equipment off.

| Required Maximum Noise levels | |
|---|---|
| Area | Maximum Noise Level NC |
| Auditoriums | 20-25 |
| Conference rooms | 25-30 |
| Executive offices | 30-35 |
| Classrooms | 30-35 |
| Open-plan offices | 35-45 |
| Dining rooms, offices, and lobbies | 40 |
| Central sterile food service/serving | 45 |
| Operating rooms | 40-45 |
| Research laboratories | 40-45 |
| Corridors and support areas | 45 |
| Kitchen, lockers, warehouse, and shops | 50 |
| Research animal housing areas | Note 1 |

*Note 1: When evaluating the noise levels in research animal housing areas, it is necessary to consider both the people and the animals in these spaces. For reasonable speech communication in these spaces, a maximum noise level of NC-45 shall be maintained. The acoustical consultant shall determine specific requirements for animal research areas on a per project basis with the Project Officer and research staff.*

The above NC values may be increased for unitary or user equipment installed within occupied spaces as approved by the Project Officer. For adequate speech intelligibility at a distance of 1.8 m (6 ft.), with normal voice effort, the background noise level shall not exceed 50 dB (A) or NC-45. In addition, the background noise spectrum shall not interfere with speech intelligibility. Since the bulk of speech intelligibility is in the 500 to 4,000 Hz octave bands, sound levels shall be lower in that area. A goal of NC-45 is equal to 53 dB (A) and has been designed to account for the frequency distribution of speech intelligibility. NC-45 shall be used as a maximum design goal for occupied research areas. The A/E shall prepare an acoustical analysis to ascertain compliance to the NC levels listed herein.

### A.1 Ductwork sound control

Construction Documents shall include all systems necessary to control noise transmitted through the ductwork system. Duct lining is not permitted in NIH facilities for either acoustical or insulation purposes; sound attenuators shall be used for controlling noise as appropriate.

## 6-5-10 Design Guidance

### A. Machinery Airborne Sound Level Criteria:

The maximum allowed airborne sound power levels from the Mechanical system equipment shall not exceed the values listed in the table below. For each piece of machinery in the human environment, do not exceed the maximum airborne sound levels 84 dB (A)-weighted scale, continuous or intermittent.

| Maximum Airborne Sound Power Level from Machinery (dB) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Equipment | Octave Band Level Center Frequency (Hz) | | | | | | | |
| | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| Air Handling Unit | 94 | 90 | 89 | 89 | 89 | 84 | 82 | 79 |
| Make-Up Air Fan | 91 | 91 | 80 | 84 | 82 | 76 | 71 | 65 |
| Air Conditioning Unit | 100 | 96 | 90 | 89 | 86 | 80 | 75 | 72 |
| Boiler | 75 | 72 | 72 | 75 | 76 | 63 | 55 | 50 |
| Chiller | 98 | 98 | 96 | 95 | 93 | 94 | 88 | 81 |
| Cooling Tower | 110 | 110 | 105 | 102 | 98 | 95 | 92 | 87 |
| Air Compressor | 90 | 89 | 92 | 93 | 92 | 92 | 90 | 81 |
| Pump | 85 | 80 | 82 | 82 | 80 | 77 | 74 | 72 |
| Fan | 55 | 50 | 48 | 47 | 48 | 46 | 42 | 37 |

## B. Machinery Vibration Criteria:

Vibration isolator types and minimum static deflection shall follow the requirements listed in Exhibit X6-5-A. The A/E shall edit these requirements to accommodate the project specific requirements.

## C. Piping and High Pressure Ductwork Vibration Isolation Criteria:

Vibration isolators shall be provided as follows:

- High Pressure Ductwork, > 1.494 kPa (6 in. wg): For a distance of 15 m (50 ft.) from fans, exhausters and blowers.
- Piping Connected to Vibration Isolated Machinery: For a distance of 15 m (50 ft.) or 50 pipe diameters, whichever is greater or to the flex connector.
- Steam Pressure Reducing Valves: Connected piping for a distance of 15 m (50 ft.) or 50 pipe diameters, whichever is greater.
- Condenser Water: For the full length of the piping. Implementation of this requirement is optional for condenser water for cold rooms, small computer room unit and small process chillers when motor are smaller than 7.5kW (10 HP).
- Chilled and Hot Water Piping: For risers from pumps and for the first 6 m (20 ft.) of the branch connection of the main supply and return piping at each floor. Implementation of this requirement is optional on systems coming from floor mounted pumps on vibration isolators with flex connectors.
- Water and Steam Distribution Piping: Resiliently support piping with combination spring and neoprene isolation hangers. Provide spring elements with 16 mm (5/8 in.) static deflection; install the hanger with spacing so that the first harmonic natural frequency is not less than 360 Hz. Provide double-deflection neoprene elements. For the first two isolation hangers, from the rotating equipment, for piping systems smaller than 100 mm (4 in.), ensure a deflection equal to the equipment-isolation static deflection. For the first four piping isolation hanger supports, from rotating equipment, for piping systems 100 mm (4 in.) and larger use resilient hanger-rod isolators at a fixed elevation regardless of load changes. Incorporate an adjustable preloading device to transfer the load to the spring element within the hanger mounting after the piping system has been filled with water.

The above minimum requirements shall be edited by the A/E to accommodate project specific requirements for piping and ductwork. Isolator deflections shall be equal to or greater than the static deflection of the vibration isolators provided for the connected machinery.

| Vibration Isolator Types and Minimum Static Deflection for Machinery | | | | | | |
|---|---|---|---|---|---|---|
| Equipment | Column Spacing (1) | | | | | |
| | Slab on-grade and 0 - 9 meters (0 – 30 ft.) | | 9.1 – 12 meters (31 – 40 ft.) | | 12.1 – 15 meters (41 – 50 ft.) | |
| | Isolator Type (3) | MSD (2) mm (in.) | Isolator Type (3) | MSD (2) mm (in.) | Isolator Type (3) | MSD (2) mm (in.) |
| Absorption Refrigeration Machines | S-R | 25 (1) | S-R | 45 (1.75) | S-R | 45 (1.75) |
| Centrifugal Chillers or Heat Pumps | | | | | | |
| - Hermetic Type | S-R | 45 (1.75) | S-R | 45 (1.75) | S-R | 69 (2.75) |
| - Open Type | S -I | 45 (1.75) | S-I | 45 (1.75) | S-I | 69 (2.75) |
| Reciprocating Air/Refrig Compressors | | | | | | |
| - 500 to 750 rpm | S-R | 45 (1.75) | S-R | 69 (2.75) | S-R | 94 (3.75) |
| - 751 rpm and up | S-R | 45 (1.75) | S-R | 69 (2.75) | S-R | 94 (3.75) |
| Reciprocating Chillers or Heat Pumps | | | | | | |
| - 500 to 750 rpm | S-R | 45 (1.75) | S-R | 62 (2.5) | S-R | 88 (3.5) |
| - 751 rpm and up | S-R | 38 (1.5) | S-R | 62 (2.5) | S-R | 88 (3.5) |
| Packaged Boilers | S | 25 (1) | S | 45 (1.75) | S-R | 69 (2.75) |
| Closed Coupled Pumps | | | | | | |
| - Up to 3.7 kW (5HP) | S-I | 25 (1) | S-I | 45 (1.75) | S-I | 45 (1.75) |
| - 5.6 kW (7.5 HP) and larger | S-I | 45 (1.75) | S-I | 45 (1.75) | S-I | 69 (2.75) |
| Base Mounted Pumps | | | | | | |
| - Up to 44.7 kW (60 HP) | S-I | 45 (1.75) | S-I | 45 (1.75) | S-I | 69 (2.75) |
| - 55.9 kW (75 HP) and larger | S-I | 69 (2.75) | S-I | 69 (2.75) | S-I | 94 (3.75) |
| Cooling Towers and Evaporative Condensers | S with deflections specified for centrifugal blowers when springs are supported on beams. Use deflection listed for column supported floors with up to 9 m (30 ft.) column spacing when springs are located on columns or bearing walls. | | | | | |
| Factory Assembled Air Handling Equipment AH, AC and HV Units (4) | | | | | | |
| - Suspended Units (4) | | | | | | |
| Up to 3.7 kW (5 HP) | H | 25 (1) | H | 25 (1) | H | 25 (1) |
| 5.6 kW (7.5 HP) and up to 29.8 kW (40 HP) - Up to 400 rpm | H | 45 (1.75) | H | 45 (1.75) | H | 45 (1.75) |
| 5.6 kW (7.5 HP) and up to 29.8 kW (40 HP) - Over 400 rpm | H | 25 (1) | H | 45 (1.75) | H | 69 (2.75) |
| 37.3 kW (50 HP) and larger | H | 45 (1.75) | H | 69 (2.75) | H | 88 (3.5) |
| - Floor Mounted Units (4) | | | | | | |
| Up to 3.7 kW (5 HP) | S | 25 (1) | S | 25 (1) | S | 25 (1) |
| 5.6 kW (7.5 HP) and up to 29.8 kW (40 HP) - Up to 400 rpm | S-R | 45 (1.75) | S-R | 45 (1.75) | S-R | 45 (1.75) |
| 5.6 kW (7.5 HP) and up to 29.8 kW | S-R | 25 (1) | S-R | 45 (1.75) | S-R | 69 (2.75) |

| Vibration Isolator Types and Minimum Static Deflection for Machinery | | | | | | |
|---|---|---|---|---|---|---|
| Equipment | Column Spacing (1) | | | | | |
| | Slab on-grade and 0 - 9 meters (0 – 30 ft.) | | 9.1 – 12 meters (31 – 40 ft.) | | 12.1 – 15 meters (41 – 50 ft.) | |
| | Isolator Type (3) | MSD (2) mm (in.) | Isolator Type (3) | MSD (2) mm (in.) | Isolator Type (3) | MSD (2) mm (in.) |
| (40 HP) - Over 400 rpm | | | | | | |
| 37.3 kW (50 HP) and larger | S-R | 45 (1.75) | S-R | 69 (2.75) | S-R | 88 (3.5) |
| Centrifugal Blowers (4) | | | | | | |
| - 175 - 224 rpm | S-R | 119 (4.7) | S-R | 119 (4.7) | S-R | 119 (4.7) |
| - 225 - 299 rpm | S-R | 94 (3.75) | S-R | 94 (3.75) | S-R | 94 (3.75) |
| - 300 - 374 rpm | S-R | 69 (2.75) | S-R | 94 (3.75) | S-R | 94 (3.75) |
| - 375 - 499 rpm | S-R | 69 (2.75) | S-R | 88 (3.5) | S-R | 94 (3.75) |
| - 500 rpm and higher | S-R | 45 (1.75) | S-R | 69 (2.75) | S-R | 94 (3.75) |
| Utility Fans (4) | | | | | | |
| - Suspended | H with deflections specified for centrifugal blowers but not to exceed 69 mm (2.75 in.) | | | | | |
| - Floor-Mounted | S-R with deflections specified for centrifugal blowers but not to exceed 69 mm (2.75 in.) | | | | | |
| Internal Combustion Engines and Engine Driven Equip - 750 rpm and over | S | 38 (1.5) | S | 62 (2.5) | S | 88 (3.5) |
| Electrical Transformers | | | | | | |
| - Suspended units | H | 25 (1) | H | 25 (1) | H | 25 (1) |
| - Floor mounted units | NP | 10 (0.35) | NP | 10 (0.35) | NP | 10 (0.35) |

*Notes:*

*(1) Table applies to 100 (4 in.) to 200 mm (8 in.) thick slab on-grade or column supported. This table applies to non-seismic zones*

*(2) Minimum Static Deflection (MSD). These are certifiable minimum deflections, not manufacturer's nominal deflections*

*(3) Equipment Vibration Isolation Schedule Designations. Hyphenated designations are combinations of the following:*

- *H Spring isolator hangers for suspended equipment and piping. Where required, provide with adjustable preloading devices.*
- *I Concrete inertia bases with steel forms.*
- *NP Neoprene pads*
- *R Welded structural steel rail for equipment mounts.*
- *S Freestanding spring isolators (floor-mounted equipment).*
- *SX Protected/housed freestanding spring isolators with adjustable cushioned vertical stops and cushioned horizontal stops. Protected spring isolators SX may be substituted wherever S is specified and shall meet all requirements.*

*(4) Fans*

- *a. When fan motors are 44.7 kW (60 HP) or larger, use the deflection requirements for the next wider column spacing. Except for equipment slab on grade, a minimum of 62 mm (2.5 in.) deflection shall be used unless larger deflections are specified in the centrifugal blower table.*
- *b. Provide sway brace isolators for tubular centrifugal and axial fans when the fan pressure exceeds 1 kPa (4 in. wg).*
- *c. Provide concrete inertia bases "I" in lieu of welded structural steel rails "R", when the fan pressure exceeds1 kPa (4 in. wg).*
- *d. Provide thrust restraints to eliminate the need for or reduce the magnitude of inertia mass when the mass is only used to reduce the displacement effects of the thrust. Provide thrust restrains for high static pressure fans, Over 1.5 kPa (6 in. wg) static pressure, and other thrust producing machinery.*

# Section 6-6: BSL3 & ABSL3 Biocontainment



## 6-6-00 Design Requirements

### A. BSL3 & ABSL3 Biocontainment spaces

BSL3 laboratories and ABSL3 animal facilities shall comply with all requirements included in the previous sections of Chapter 6 “HVAC”. This section includes additional requirements to be included in level 3 biocontainment laboratories (BSL3) and biocontainment animal facilities (ABSL3). Design of BSL3 and ABSL3 shall be reviewed and approved by NIH/DTR and NIH/DOHS.

Refer to Section 2-5 and 2-6 for additional requirements for the design of BSL3 and ABSL3 facilities.

### B. Supply Air Systems in BSL3 Laboratories:

BSL3 laboratory spaces shall be provided with dedicated supply air systems, which do not serve any other laboratory spaces outside the containment laboratory. Refer to Chapter 7 “Building Automation Systems” for detailed control requirements and pressure control requirements.

### B.1 Space Ventilation Rates in BSL3 Laboratories:

BLS3 laboratories shall be provided with a minimum of 6 air changes per hour. This minimum air flow shall be maintained at all times, including unoccupied periods. Air ventilation system shall be designed to remove all heat dissipated by all equipment within the lab space and all exhaust air requirements from fume hoods, BSCs, sterilizers, etc

### C. Supply Air Systems in ABSL3 Animal Facilities:

ABSL3 animal spaces shall be provided with dedicated supply air systems, which do not serve any other animal facilities/spaces outside the containment space. BSL3 and ABSL3 may not be combined to a common system. ABSL3 spaces shall be provided with local temperature and humidity monitoring and controls. Refer to Chapter 7 “Building Automation Systems” for detailed control requirements and pressure control requirements.

## C.1 Ventilation rates in ABSL3 Animal Facilities:

Ventilation rates in animal facilities are typically 10 to 15 outdoor-air changes per hour (ACH). Refer to Section 6-1 for additional requirements. Ventilation rates shall be reviewed and approved by NIH/DTR and NIH/DOHS

## D. Relative Room Pressurization:

Airflow in biocontainment facilities BSL3 and ABSL3 shall be designed to move from "clean" areas toward the biocontainment space. The system shall be designed to maintain a negative pressure differential of 12.5 Pa (0.05 in. wg). Monitoring and control devices shall be provided to insure that the pressure differential is maintained. Visual readout devices and alarm devices shall be provided to notify users of any loss in pressure and/or loss of containment.

## D.1 Anterooms:

Anterooms shall be located between the BSL3/ABSL3 and the clean corridor outside the biocontainment space. These anterooms are typically negative to the clean corridor and positive to the BSL3/ABSL3 spaces keeping the contents in the biocontainment room from leaving the room. That is, the BSL3/ABSL3 room is negative to the anteroom. The use of anterooms needs to be reviewed with NIH/DTR and NIH/DOHS.

## E. Exhaust Air Systems:

BSL3 spaces shall be provided with dedicated exhaust air systems. BSL3 and ABSL3 may not be combined to a common system or any other system serving spaces outside the biocontainment space. This dedicated exhaust air system shall include: pressure-independent constant-volume air terminal units, roof-mounted exhaust fans, VFD for filter loading and/or for multiple rooms applications, exhaust stacks, HEPA filters, etc. Refer to Chapter 7 "Building Automation Systems" for detailed control requirements and pressure control requirements.

## E. Air Filtration:

Supply air serving BSL3 laboratories and ABSL3 animal facilities is not required to be HEPA filtered.

Exhaust air HEPA filtration is recommended and each particular system/application shall be reviewed with the user, NIH/DTR and NIH/DOHS. If HEPA filtration is not required, the exhaust air system shall be designed with provisions for adding the HEPA filtration in the future.

HEPA filters shall be located as close as possible to the containment barrier penetration. HEPA filters shall be rated for 99.99% efficiency at 0.3 microns. These filters shall include provisions for bag-in/bag-out filter replacement. HEPA filters shall be located with consideration to replacement and testing procedures. HEPA filters shall be zoned so that shut downs can be coordinated. Consideration shall be given to provide redundant filter banks in case of un-planned laboratory shut-downs.

The HEPA filter housings shall be welded stainless steel construction. Each HEPA filter shall be capable of in-situ decontamination and full face scanning. Bubble tight dampers with end switches shall be used for HEPA filter isolation. Bubble tight dampers shall be of the positive seal type with zero leakage and rated for the pressure classification of the system.

## F. Autoclaves:

Autoclaves serving BSL3 and ABSL3 shall be provided with stainless steel exhaust canopy hoods over the door to empty the autoclave. In the case of double sided autoclaves with dual direction flow, canopy hoods shall be provided over each of the two doors used to empty the autoclave.

The need for HEPA filtration of the exhaust air from the canopy serving the dirty side of the autoclave shall be reviewed by NIH/DTR and NIH/DOHS

## G. Variable Frequency drives:

Following a power outage and the initiating of the emergency electrical power, all Variable Frequency Drives associated with supply and exhaust fans serving BSL3 or ABSL3 spaces, which are required to maintain biocontainment, shall be provided with the ability to restart into a coasting motor without delays and without damaging the motor. That is, the drive shall be able to catch the motor on the fly. The drive shall be able to identify motor rotation and when the opposite rotation is detected, slow the motor down to zero speed, otherwise, smoothly accelerate the motor to the commanded speed with the correct direction without tripping on an over-voltage or over-current condition. Mechanical brakes or anti-ratcheting devices can be used to ensure that a fan doesn't rotate in the wrong direction.

## H. Emergency Electrical Power:

Supply air fans, exhaust air fans and all devices and equipment serving and/or associated with BSL3 and ABSL3, which are required to maintain biocontainment of the space shall be connected to an emergency electrical power system.

# 6-6-10 Design Guidance (Reserved)

# 6-6-20 Design Information (Reserved)

# 6-6-30 Design Document Requirements

## A. HVAC Plans

All design phases of the Construction Documents shall be reviewed and approved by NIH/DTR and NIH/DOHS.

## B. Testing, Validation and Certification:

Construction documents for BSL3 and ABSL3 facilities shall include the requirement to comply and obtain the BSL3 Laboratory certification in accordance with the requirements in the NIH Biosafety Level 3 – Laboratory Certification Requirements.

- NIH Biosafety Level 3 - Laboratory Certification Requirements

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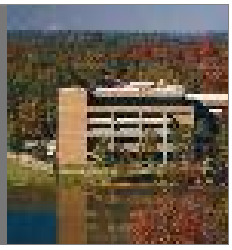
# BAS 7





# Section 7-1: BAS Design Considerations



## 7-1-00 Design Requirements

The following design requirements apply to all BAS. The goals and objectives are to provide uniformity of design; combine the best overall economy with suitability of design; and be compatible with all other building systems. Provisions for future expansion shall be made as determined by NIH on a project-by-project basis.

The BAS is configured as a network with control functions at multiple levels and with multiple points of operator control and supervision. The BAS includes central servers, local building engineer's workstations, data transmission systems, field panels and controllers, necessary interfacing controls, sensors and actuators. The controller contains a microprocessor and other supporting electronics, and performs local control functions and executes application programs without requiring communications with the central server or workstations. All new facilities shall use digital controls in accordance with the DRM. The A/E's and the Project Officer shall meet with maintenance staff early in the project to coordinate new digital controls with existing.

### A. Scope:

The DRM applies to BAS that control and/or monitor all systems in the building with the exception of the following:

- Chilled Water plants involving chillers and cooling towers, etc. The DRM covers building level connections to a campus system or other chilled water plant.
- Hot water or steam plants including boilers. The DRM covers building level connections to campus steam or hot water generating systems.
- Vivarium lighting systems.
- Scientific Equipment Monitoring Systems.
- Fire Alarm Systems.
- Elevators.
- Security.

# 7-1-10 Design Guidance

## A. Intent:

### A.1 General Intent:

The DRM requires fully automated, reliable but cost effective direct digital control systems for all building systems and requires the A/E's:

- To establish a level of quality for the control systems installed at the NIH.
- To promote and facilitate consistency among the numerous projects.
- To establish the extent of the control system that is required and cost effective for the NIH, synthesizing the requirements of the design, management, and operations of the facility.
- To establish preferences relative to the BAS.

## B. Functional Intent:

### B.1 Standardization:

BAS installations shall strive for standardization across institutes and operating organizations to maintain consistency and thereby increase reliability. It is the responsibility of the institute and/or operating organization to define and present those standards to the design and construction community. To some extent the DRM contributes to that standardization, however, the DRM presents concepts which must be further defined as how they apply to the various organizations.

### B.2 Access Requirements:

BAS shall have the capability of granular assignment of rights to individual methods, areas, systems, information, etc. Individual users shall be given one account name and password and regardless of where they connect they will be granted access to only those functions they are authorized to use.

# 7-1-20 Design Information

## A. Design Coordination:

The A/E shall coordinate with the organizations that will support or use the BAS. As representative examples, the A/E shall coordinate through Project Officer:

- With the Operating Organization for:

    1. A building system telecommunication hub and required building support hardware system for significant dial up telephones and intranet/internet connectivity support for equipment alarm and building control system. The A/E as part of their coordination efforts shall develop a clear scope of work for control contractor relative to the LAN and its point of connectivity with institute provided services and required interface hardware as part of their design. Requirements for IP addresses shall be established and secured through Project Officer.
    2. Point naming conventions.
    3. Equipment numbering conventions.
    4. Graphic formats and layouts.
    5. Location of operator interfaces and required number of portable operator workstations.
    6. Training requirements, etc.
    7. Required user accounts and levels of access.
    8. Routing of alarms and notifications.

- With the using agencies for required control parameters and condition tolerances.
- With the applicable safety organization for required control parameters and condition tolerances.

# 7-1-30 Design Document Requirements

## A. General Design Requirements:

### A.1 Contract Documents:

Projects that involve BAS shall include a detailed control system design. Design shall be accomplished by properly qualified personnel knowledgeable in the applicable control systems. The design documents shall include, at a minimum:

- Specifications detailing the BAS requirements.

- Schematic drawings indicating the systems/zones and all control system input and output.
- List of all points with summary counts.
- Detailed written sequences of operation.
- BAS infrastructure schematics.
- Valve schedules.
- Indication of control elements on the applicable discipline design floor plans (this refers to panel locations, operator interface locations, thermostats, temperature and humidity sensors whether in the room or in the return/exhaust duct, room differential pressure monitors, duct static pressure sensors, motor operated dampers, automated valves, etc.). It is not necessary to show on the floor plans specific components that are within a unit as long as a schematic is shown for that unit and that unit is shown on the floor plan.

## B. Design Specifications and Drawings:

The A/E shall provide control specifications and drawings detailing the requirements of the BAS hardware and software. At a minimum, the specifications and drawings shall:

- Detail the minimum quality on all hardware commensurate with the DRM.
- Define the control system documentation required commensurate with the DRM.
- Define the level of controller allowed for each specific control application on the project along with the stand-alone functionality required.
- Specify all wiring and tubing requirements.
- Clearly delineate limits of responsibility and/or dictate various requirements in the specific context of the system. As examples of this requirement:

    1. The scope of laboratory grade control systems verses commercial control systems shall be clearly identified.
    2. Responsibility for mounting of terminal controllers shall be indicated.
    3. Responsibilities for furnishing, installing, calibrating, and commissioning valves and dampers, standard and laboratory grade VAV terminals, sash sensors and hood monitors, general field devices, etc. shall be defined.
    4. Responsibilities for balancing/calibrating various BAS sensors (TAB verses control contractor) shall be defined and coordinated with the TAB section of the specifications.
    5. Coordinate the limits of work and for connection of the BAS to the existing supervisory net-work.

- Specify quality and quantity of graphic interfaces to be developed for the project.

- Detail the security permissions to be established for this project. This shall require consultation with maintenance staff.
- Detail the commissioning activities required with reference to the NIH Commissioning Guideline.
- Detail both the trending capabilities required of the BAS as well as the project specific requirements for setting up trends and archiving data.
- Define the warranty period and maintenance requirements.
- Define the training required. Training requirements shall be applicable to the project and coordinated with maintenance staff.
- Reference applicable NIH testing protocols such as fume hood testing.
- Detail sequence of work for renovations in existing facilities to minimize disruption.
- Define emergency notification and alarming requirements the DRM. Alarm thresholds shall be dictated on applicable values and level/means of alarm notification shall be specified
- Define graphic user interface software functional requirements commensurate with the DRM.
- Define direct digital control software functional requirements commensurate with the DRM
- Detail AAALAC required monitoring and documentation requirements of the systems controlling vivaria.
- Detail and coordinate interfaces to other systems such as lighting control systems, laboratory monitoring systems and power monitoring systems.
- Define a point naming convention the DRM.
- Define the record documentation requirements the DRM.
- Define the point of connection to the existing network as defined below.
- Require bandwidth calculations and analysis to be submitted by controls contractor to validate either the response time for deterministic networks or percent utilization for CSMA/CD networks under a fully loaded condition with specified trending.
- Coordinate with the operations and maintenance staff for required nomenclature on terminal units. Where air flow tracking boxes serve a room, or where multiple HVAC elements control the same zone, clearly indicate the pairing relationships in a table or by nomenclature. Requiring the controls contractor to interpret the ductwork or piping drawings to assess pairings is not acceptable.
- Clearly outline the requirements for stand alone capability of controllers controlling multiple tracking boxes in containment and high containment (BSL3 and BSL4) suites, isolation suites and vivaria.
- Clearly outline the requirements for the stand-alone capability for controllers as well as the method for coordinating several stand alone controllers controlling a common function across controllers. For instance, the method for controlling the static airflow/static

pressure of separate air handlers on a common headered system shall be specifically detailed.
- Concurrent access client software licensing requirements. The A/E shall consider the construction and commissioning requirements which may in some cases require a higher quantity of concurrent sessions to the client/server software.
- Show on the drawings limits of stand alone control requirements of containment and high containment suites as defined below.

## C. Design Control Schematics:

The A/E shall include in the contract documents detailed control schematics of all systems and zone configurations. Control schematics at the design stage shall include the following at a minimum:

- Point Names.
- Point Type.
- Normal position of output devices.
- Device ranges.
- Initial design intent set points (to be modified as refined during construction for record submittals.)
- Bill of Materials listing all devices.
- Legend of device symbols.
- Basic motor starter and interface wiring schematics.

The locations of flow meters shall be shown on the piping or duct drawings. Remote static pressure sensors for capacity control of air and water systems shall also be shown on the design drawings.

### C.1 Design Points List:

The A/E shall provide a listing of all physical I/O with relation to system and controller listed. The points list shall include as a minimum:

- Point Type (AI, BI, AO, BO, PI, etc)
- Point quantity with summaries by point type, summed by controller and system

### C.2 Detailed Written Sequence of Operations:

The A/E shall provide a detailed written sequence of operation. This sequence shall provide at a minimum:

- Sequences in all modes of operation On, Off, Occupied, Unoccupied, Warm-up, Cool down, summer, winter, Economizer, etc.
- Details of operation during and after a power outage. Require that loss of status associated with power outages are not indicated as failures with a subsequent alarm.
- Specific direction on failure scenarios for loss of proof and all safety device trips.
- Set points, trip points, and ranges. Initially these shall be the A/E's intent, and eventually be the actual setting at time of record submittal.
- Detail the requirements for loop response and tolerances for control.

## C.3 BAS Infrastructure Diagrams:

The A/E shall include in the contract documents a diagram that depicts the intended architecture of the BAS infrastructure. Diagram shall show all control and supervisory LAN's, graphic user interfaces, alarm enunciators and printers, routers, gateways, controllers (terminal controllers can be grouped), etc. Each LAN shall be indicated with intended media and protocols. Location of Graphic User Interfaces shall be identified. Point of interface for Institute supplied LAN media shall be depicted. Also, depict point of connection for interfaces

## C.4 Valve Schedule:

The A/E shall select and schedule valves. Selection shall be made to facilitate smooth and stable control. Either with the control schematic or separately in contract documents, shop drawing submittal and record submittal provides a valve schedule listing the following:

- Size.
- Valve Type.
- Actuator Type.
- Cv.
- Design flow.
- Design pressure drop.
- Close off rating.
- Normal positions.
- Valve characteristic (i.e.: equal percentage, linear).
- Manufacturer (basis of design).
- Model number (basis of design).

# Section 7-2: BAS Infrastructure



## 7-2-00 Design Requirements

### A. General Infrastructure Requirements:

The BAS shall be an integrated digital control system composed of a tiered LAN architecture connecting supervisory servers/interfaces and distributed stand-alone multi-level controllers. Supervisory graphic software system configuration and backup software shall use a client/server architecture to store and serve the graphics, user databases, system configuration databases, site controller programming backup/Upload/download, g configurations, etc.

The Supervisory LAN shall often be an existing system. Controlling LAN's shall then connect new controllers. The supervisory LAN/WAN shall be provided by the applicable Institute to the point dictated in the contract documents. Controlling LAN's shall be provided by the contractor.

Exception: Where the primary controlling LAN is a subnet or segment of the Institute intranet, the LAN infrastructure may be provided by the Institutes data provider.

## 7-2-10 Design Guidance

### A. Integration with Existing Systems:

Any new BAS system shall fully integrate with existing BAS installations. The government's project officer shall facilitate a meeting between the A/E and maintenance staff early in the project to coordinate the new work with the existing digital controls. Fully integrate shall mean the following:

- All physical and virtual I/O shall be displayed on and modifiable (spawning a point specific configuration menu from the graphic is acceptable) from a standard graphic on one of those systems.
- Indicated points shall be able to be overridden and/or put in test mode from existing supervisory system. Digital controls manufacturers that do not have this capability can work around it by making the control point a virtual point referencing the physical point.

- Security restrictions set on the existing system shall duly restrict access throughout the new system.
- All alarm routing functionality required herein shall be provided on the existing system when alarms occur on the new system.
- Schedules on the new system shall be readable and modifiable from one of the existing graphic user interfaces.
- Point configuration databases shall be stored on one of the existing servers.
- Site specific controller programming shall be stored (back up) on one of the existing system's servers and the controller programming shall be modifiable from the existing system and the programming stored on the server shall be uploadable/downloadable between the new field controllers and the existing servers.
- Trends of points on the new system shall be able to be configured to accumulate in the buffer of the field controller and periodically uploaded to one of the existing servers for storage/archiving.
- All points and tuning parameters on the new system shall be assessable and modifiable from any one of the existing workstations.
- All alarms shall be displayed on all existing workstations.
- All point databases shall be setup to meet the existing point naming conventions.

## B. Integration between Newly Installed Systems:

Two or more independent DDC systems shall not be provided. Multiple manufacturers may be integrated into one system, however, to keep the system simple and the parts interchangeable, the A/E is encouraged to use as few manufacturers as practical and preferably one manufacturer. When multiple control products are installed at NIH on a given project, they shall seamlessly integrate such that all information from the subordinate system shall be accessible and modifiable from the supervisory system. One supervisory system shall be provided for the entire system with full functionality. Using two independent systems to meet the requirements of the DRM is unacceptable. Examples of where these requirements apply and the systems shall be integrated include:

- DDC manufacturer uses another manufacturer's laboratory tracking control system.
- DDC manufacturer uses another manufacturer's variable speed drive chip.
- DDC system manufacturer uses a project specific local control system such-as with self-contained computer room unit.

# C. Controller Networks:

## C.1 General Controller Networks:

Controller networks are LAN's that connect various grades of controllers. The BAS consists of tiered controller LAN's in that a primary control network shall connect primary controllers, and operator interfaces, and secondary networks shall connect secondary or terminal controllers. The secondary control networks communicate with the primary control network by a gateway either stand alone or packaged in a primary controller. The primary networks are defined as high-speed networks that incorporate peer-to-peer protocols. Secondary networks are slower networks for that may depend on a single master device to control the communication on that network thus the communications are less reliable and only applicable to less critical applications. What determines a primary verses a secondary network is indicated below.

## C.2 Primary Controller LAN:

A primary controller LAN is defined as high-speed peer-peer LAN used to connect primary controllers, which control larger and more critical equipment and may form gateways to other LAN's. These may either incorporate deterministic protocols such as Arcnet (IEEE802.4) or proprietary Token Ring derivatives, or CSMA/CD protocols such as Ethernet (IEEE802.3) or LonTalk. In any case, the failure of any one device shall not stop communication on that LAN.

Each new facility shall include a primary controller LAN provided by either the control vendor or by the Institutes data provider. The A/E shall establish limits of responsibility in the design as indicated above.

## C.3 Secondary Controller LAN:

The secondary controlling LAN is defined as a LAN that connects secondary controllers. This may utilize polling and/or master-slave scenario since it is not intended to support critical information transport.

## C.4 Gateways, Switches, and Routers:

Control vendor shall define all necessary gateways, switches and routers to efficiently segment/architect the LAN. Where controlling LAN's are provided by the BAS contractor, BAS contractor shall provide all devices. Where the controlling LAN's are installed by the Institutes data provider, BAS contractors shall specifically define all requirements for segmenting, routing, reliability, etc. Gateways and routers shall be powered by uninterruptible power sources and emergency power to ensure seamless and continuous communication across the LAN.

## C.5 Configuration of Control LAN's:

Building architecture and its utility functions shall be adapted to the needs of the building automation system. The network components shall be centrally located on each floor and co-located with LAN closets (where applicable) to share vertical and horizontal wire ways.

Control panels shall be located proximate to the equipment they serve to minimize the cost of I/O wiring and piping and make the system less vulnerable. Control panels shall however be mounted in protected environments such that they are not subject to physical damage, vibration, nor excessive temperature. The equipment rooms, where practicable, shall have ambient conditions between 16°C (60°F) and 52°C (125°F) and 10% to 85% relative humidity. Control panels located in areas exceeding these ranges shall have enclosures with heating or cooling devices to provide the proper environmental conditions.

The building engineer must have quick direct access to all control panels to maintain building integrity similar to that provided for fire emergencies without going through tenant spaces. Field panels shall be located out of tenant areas where practical. If field panels are located in tenant areas, they shall be in common areas with easy access. Protection and separation for tenant activities shall be provided.

# D. Servers:

## D.1 Description:

As the DRM requires client/server architecture, the BAS shall include a Server computer to store all the information required by the BAS and manage client access to that server.

## D.2 Functional Requirement:

The server may be a single computer or a server farm; however, the database shall be common to the entire BAS and allow back up and recovery from one backup system.

Server shall allow multiple user access and manage user access and changes to the common BAS database. Server shall be selected with reliability, fault tolerance and processor speed necessary to support the expected number of clients and controllers on the system. Server shall have the disc storage capability to store all the graphics, database, third party applications, system activity logging and trend archiving required for the application for the entire enterprise. In many cases, the server will be responsible for meeting the response time requirements for user access to graphics. The server shall be powered by an uninterruptible source with the capability to maintain the server through power transitions.

# E. Operator Workstations:

## E.1 Description:

Operator workstations are primarily passive in that they are only used to facilitate human interaction with the control system and do not execute any automatic control. In some cases, the same computer used for the operator workstation may be also be used as the gateway or router between the supervisory network and the Primary Controller LAN. Hardware requirements of the Operator Workstations are indicated in the Installation Requirements section of the DRM

## E.2 Placement/Connections:

Provide for the following with regards to placement of or connections for operator workstations:

- Provide at least one graphic operator's workstation in the engineer's office of each facility.
- Provide at least one graphic operator's workstation in the building manager's office of each facility.
- Provide at least one connection for a portable graphic operator's workstation in each "major" (as dictated by the project officer) mechanical room. The functional intent of these connections is to support maintenance activities from within the room. Connection point shall be clearly labeled.
- Where the vivarium monitoring is being provided by the client application of the BAS, provide one in the vivarium manager's office.

## E.3 Functional Requirements:

Functional requirements of the operator workstations are indicated in the Installation Requirements of the DRM.

## E.4 Client Software:

As the architecture of the BAS is to be client/server, Operator workstations shall either run client software or terminal sessions on the server. The client software may run as either "thick" or "thin" client. A thick client shall be a software package that is stand alone but connects to the server backend databases to serve system information. A thin client is one that shall run through a browser such as Microsoft's Internet Explorer with no more than a "plug in" (freely and automatically distributed). A terminal session is one in which the client directly accesses the server and runs an instance of the graphic interface software on the server from a remote computer. Any modifications done to the system via the thin client provided as an operator workstation shall modify the primary server information presuming the user

has entered the appropriate password level. If for instance separate graphics must be produced to support the browser-based interface, the browser-based software does not qualify as either a portable or stationary Operator Workstation.

For all projects that incorporate a balancing contractor, control vendor shall provide the TAB contractor with a device and/or software (laptops or pocket pc's must be provided by the TAB) that facilitates balancing/calibrating flow controlled systems like VAV terminals. Connections shall be provided from within the zone the terminal is controlling.

For all projects, control vendor shall provide a client version of the graphic interface software, licensed for the entity that is performing the commissioning activity for the duration of the construction and warranty period. This shall be a license that is then later transferred back to the applicable institute. The functional requirement here is to provide full functionality of the graphic interface software to the commissioning effort. If this can be done via a browser or a terminal session, these are also acceptable.

## E.5 Portable Operator Workstations:

The requirements shall be coordinated with maintenance staff on a project-by-project basis. A Portable Operator Workstation refers to a laptop computer or pen tablet that can fully run the client software, browser, or terminal session as applicable.

## E.6 Vivarium Monitoring Workstations:

The following shall be made automatically available to the veterinarian:

- Real time graphic interface to floor plans with all relevant environmental parameters displayed or accessible
- Real time (maximum 20 minute lag) alarming of conditions of the relevant environmental parameters
- Sample and record the following parameters in each animal holding room:

    1. Temperature (15 minute intervals).
    2. Humidity (15 minute intervals).
    3. Air Change Rate (15 minute intervals).
    4. Lighting Level (Change of Value) Note: This item is a recommendation and shall only be included by direction of the veterinarian and Project Officer.

- Provide the following alarm information:

1. Maintain an alarm log of all parameters currently in alarm and when they went into alarm.
2. Maintain a daily log recording when they went into alarm, the maximum excursion, and when the alarm condition was cleared.

- Provide the following formatted reports. These reports shall be printed or displayed when manually initiated:

1. Current Alarm Summary indicating all points currently in alarm.
2. Daily Alarm Summary indicating all alarms for a selected day.
3. Daily room summary indicating average, high, and low values for temperature, humidity, and air change rate.
4. Lighting Report representing a graphical indication of when lights are on or off on a two-dimensional grid showing time of day as a horizontal axis and the room number as the vertical axis (when lighting is included as a sampling parameter by program direction only).
5. AAALAC Report indicating current poll data for: temperature, humidity, supply airflow, exhaust airflow, and air change rate.
6. Room Graphs indicating a 24-hour graph of a room's temperature, humidity, and air change rate.

## F. Response Time Requirements:

The communication speed between the controllers, LAN interface devices, and operator workstations shall be sufficient to ensure fast system response time under any loading condition. The A/E shall include in the specifications that the contractor shall submit guaranteed response times with shop drawings including calculations to support the guarantee. In no case shall delay times between an event, request, or command initiation and its completion be greater than the following:

- 5 seconds between a High Priority (critical) alarm occurrence and enunciation at operator workstation.
- 10 seconds between a Low Priority alarm occurrence and enunciation at operator workstation.
- 10 seconds between an operator command via the operator interface to change a set point and the subsequent change in the controller.
- 5 seconds between an operator command via the operator interface to start/stop a device and the subsequent command to be received at the controller CU.
- 10 seconds between a change of value or state of an input and it being updated on the operator interface.

- 10 seconds between an operator selection of a graphic and it completely painting the screen and updating at least 20 points.

Requirements do not apply when a remote connection shall be established via modem or when the graphic is connected via the WAN outside of the LAN segment dedicated to the primary controlling network, however, the response times shall be proved with an operator workstation connected to the primary controller LAN.

## G. Remote Connections:

All BASs shall have the capability to be accessed remotely. The required remote connection might be via voice grade phone lines or the institute's intranet. When remotely connected, the user shall have the ability with the proper password to perform any function on the BAS that they can if locally connected.

## H. Intranet Remote Connections:

All BASs shall have the capability to be accessed via the applicable institute's Ethernet intranet given appropriate access credentials and rights configured by the Data Provider applicable to the project. Security requirements of the base system apply to intranet access, in that the server shall only allow a user access to information that has specifically been assigned as available to the user. Examples of acceptable access scenarios include:

- User uses a browser based thin client to access servers visible directly on the intranet. Credentials are entered by the user who is then granted access to the appropriate information.
- User uses a thick client application from a client station on the intranet. Client application connects to the BAS server.
- User uses a terminal session client to connect to the server and run an instance of the interface software on the server.

# Section 7-3: Application Requirements



## 7-3-00 Design Requirements

### A. General Application Requirements:

This section of the DRM defines general physical Input/Output (I/O) requirements, sequences, and by inference, some degree of system requirements related to how the BAS is applied to the building areas and systems. This section is organized by "element" of the building and systems and presented from higher-level elements to lower level elements. The elements listed can be configured in various ways to obtain the various systems as dictated in the Chapter VIII. HVAC. Strict adherence to these requirements will inevitably result in duplicate I/O (i.e.: the leaving air side of a coil will frequently be the same as the supply air). The intent is obviously not to provide redundant sensors and the A/E is to exercise professional judgment and common sense in the application of these requirements.

### B. Building Level Requirements:

### B.1 Building Level Monitoring:

Monitoring at the building level shall consist of the following points. Coordinate monitoring between the BAS and the utility monitoring system. Not all points shall be applicable to all facilities. The A/E shall provide the points applicable.

Outside Environment:
- OA Temperature.
- OA Relative Humidity.

Chilled Water Service:
- CHW Supply and Return Temperature.
- CHW Supply and Return Pressure.
- CHW flow.

Steam Service:
- Steam Use.

- Steam Pressure.
- Condensate Flow.
- Condensate Temperature.
- Condensate Receiver Level Alarm.

Electric Service:
- Electricity Use (amperage or meter pulse counter).
- Supply Voltage.
- Network Protector Status.

Emergency Electric Service:
- Generator Status.
- Generator Alarm.

Gas Service:
- Gas Use.
- Gas Pressure.

Compressed Air:
- Supply Pressure.
- Compressed Air Flow.

Domestic Water Service:
- Water Flow.
- Water Service Pressure.
- Water Load Side Pressure (after backflow preventer).

Sanitary Service:
- Effluent pH Level (when cage washing facilities are included).
- Effluent Temperature (Where heat source effluent decontamination systems are used).

## B.2 Power Transfers:

When power returns from a power outage or transfer, the systems in the building shall be restarted in priority of criticality with a slight timing delay between starts to minimize the in-rush

## C. Zone Level Requirements:

### C.1 General Occupied Zones:

This refers to all temperature controlled zones. With few exceptions, all zones of control shall require a space temperature sensor. Zoning shall be dictated by the system design. The general guidance is that, most zones shall simply have a space temperature sensor mounted in a representative location in the zone. In areas that the HVAC systems are scheduled for occupied/unoccupied cycle, at least one sensor per system shall be provided with an override button. Private offices may include space temperature adjustment with the sensor at the direction of the Project Officer. When one temperature sensor is used to control multiple thermal zones intended for occupancy by people in the various zones, sensors shall not have space temperature adjustment. Anywhere that space temperature adjustment is provided; the BAS shall allow setting the limits of the occupant's range of allowable adjustment.

In all cases, the heating and cooling within a zone shall be coordinated to avoid simultaneous heating and cooling. One exception is perimeter heat required to provide thermal comfort to occupants sitting near a window wall while the internal load in the space may still require cooling. Another is dehumidification. If wall-mounted sensors are not practical and duct mounted sensors are required, install off-the-shelve test ports.

Fail position on the systems that serve these standard environments shall fail to either last condition/position or heating where there is a perimeter wall or some need for heating. Where there is not a need for heating, such as in an internal zone, systems shall fail to either last position/condition or to cooling. Fail position for animal rooms shall be coordinated with the veterinarian and are indicated for the applicable spaces below.

Controls for a typical zone shall be indicated below with the system that serves that zone. For instance if a zone is served by a 100% OA VAV system, the temperature control for that zone shall be covered by the air handler and the VAV box. A zone served by a fan coil unit shall be covered by the fan coil unit element and the chilled water system. Controllers serving terminal devices that serve these spaces shall be application specific secondary (Terminal) controllers fed from normal power.

New non-critical zone level controls, including sensors, controllers and actuators shall be electronic. Pneumatic controls shall not be used except pneumatics may be used for critical applications that require fast response. These are defined below.

Tri-State Actuators: Tri-state actuators which require periodic recalibration of the motor timing by stroking the actuator shall be used on valves and dampers controlling spaces that do not have tight temperature, humidity, and pressure requirements. These may be used on offices, corridors not an essential component of a critical laboratory pressure gradient, conference rooms, break rooms and analogous types of rooms. They shall not be used on any other type or room without the approval of the Project Officer. They shall specifically not be used in spaces, or on support systems for, animal care areas unless it can be shown that recalibration will not result in temperature swings. Tri-state actuators may be used in the following applications:

- Laboratory and animal holding room air dampers provided that stroking the damper is not necessary to recalibrate the actuator on a scheduled basis.
- Animal holding room reheat valves where calibration will not cause excursion beyond acceptable ranges.

## D. Laboratories:

### D.1 Common Laboratory Requirements:

Laboratory zones shall have temperature control and pressure independent volume control. Pressure independent volume control shall be interpreted to mean that a set point volumetric flow rate of supply and exhaust into and out of the laboratory shall be automatically maintained regardless of fluctuations in static pressure; i.e. flow rates shall be determined based on sensor readings and the positions of dampers in the supply and exhaust air stream adjusted automatically to maintain a set point flow rate. Zone level humidity control is optional and shall only be done where required by the program occupying the space. Thus, the monitored points associated with the zone (for zone related equipment requirements, see the applicable equipment) shall be as follows:

- Space Temperature.
- Common Alarms on Hoods and/or BSCs.
- Humidity.
- Supply/exhaust velocity (total / static differential) pressure.

Note that institutes are required to have alarms on fume hoods and biosafety cabinets (BSCs) that are separate from the BAS.

Laboratories shall have pressure or directional airflow controlled zones. On existing constant volume systems where installation of pressure independent terminals is not practical, and only with permission of the Project Officer, laboratory pressurization may be done by balancing.

The requirement for pressure independent VAV zone control means that each zone shall have a pressure independent terminal box on each supply and exhaust. The pressure independent terminal box shall control a damper to achieve a set point flow rate. The set point flow rate will be automatically varied between a minimum and maximum flow rate as necessary to meet the airflow demand of the room. In some cases, an individual room on the system may require a constant flow. In these cases the minimum and maximum flow rates shall be set to the same value resulting in a constant flow to the room so that any room on the system can be converted from variable to constant volume by changing the control parameters; i.e. the conversion is done from a workstation and not in the field. Air handler shall often serve a combination of variable and constant volume zones.

On new VAV systems, laboratory zones shall be actively controlled by maintaining an offset between the total supply and exhaust flow to the room. On zones that are required to be negative, the supply flow shall track the exhaust flow. On zones required to be positive, the exhaust shall track the supply. Where feedback of the supply and exhaust flow is provided by a correlation to the damper position as in a venturi valve, an input to the system shall indicate when the duct static pressure is insufficient to validate this correlation. See below for General Pressure Controlled Rooms for more requirements.

When less than 100% redundancy is provided in either a failure mode or an emergency power mode, and the pressure is controlled at the zone level, prioritized reset of the terminal flow set points is required to maintain the required room pressurization. When this is the case, the A/E shall dictate the priorities. Controls for laboratories shall be fed from emergency power.

Monitoring of space pressure with local indication is only required when the potential threat to human well being or the research program from airborne contamination is significant and is required by the BMBL for BSL3 and ABSL3 facilities. This shall be discussed with the Project Officer and the researcher to establish this need.

Laboratory equipment shall be monitored by the Laboratory Equipment Monitoring System not covered by the DRM.

## D.2 Laboratories with VAV Hoods:

When laboratories contain VAV fume hoods, the controller and all devices shall be laboratory grade that can act with the speed of response required to meet the requirements of the NIH fume hood testing protocol. This will require fast acting actuators and require fast responding controllers commensurate with laboratory grade control systems. Conventional

VAV terminals may be used for supply and general exhaust provided they are fitted with fast acting actuators.

Each VAV fume hood laboratory shall have a pressure independent terminal box on the fume hood exhaust as well as on the supply air duct. As required by the Chapter 6. HVAC of the DRM, a General Exhaust box may be required. In that case, it shall also be a pressure independent VAV box. Room temperature shall be maintained by increasing the total zone exhaust airflow set point on a rise in temperature and by decreasing its set point on a fall in temperature (the minimum zone flow set point shall be limited to that required for air exchange). Room temperature shall also be maintained by modulating the reheat coil to maintain the heating set point. Room pressurization shall be maintained by varying the supply airflow set point to track the total zone exhaust air being measured (hood flow plus general exhaust as applicable). Exhaust air through the fume hood shall be modulated to maintain an airflow that is required to maintain a face velocity set point. Airflow set point shall be determined by sash position. The general exhaust airflow set point shall vary to maintain the total zone exhaust flow set point when the hood flow is less than that required for the cooling loop. All box dampers shall modulate to maintain the established flow set point.

## E. BSL3 Laboratory Common Requirements:

This section includes the requirements for the critical zone as well as its support systems. Critical laboratories include BSL3 and higher biosafety levels.

The interlock between the exhaust and supply shall be designed to prevent the room from pressurizing opposite from its intended direction at any time. Components shall be selected so that in any realistic failure scenario, the supply air flow rate will decrease more quickly than the exhaust for negative containment spaces or visa versa for positive spaces. This requires that the A/E consider the control sequence and actual/required responses of all drives, sensors, fans, dampers and damper actuators. Based on this the A/E shall confirm that all practical measures have been implemented to ensure maintenance of required pressure at all times. Specifically implement the following where applicable:

- Provide a hard wired interlock (between supply controller and exhaust controller) indicating exhaust system status and supply system status such that the lagging system can confirm operation of the leading system in the absence of the Controller LAN communication. The DRM re-quires this interlock for less critical laboratory spaces, however does not restrict the use of the control network to transmit the status information. Where multiple controllers are controlling the exhaust system, status outputs shall be wired in parallel.

- Zone terminal unit controllers shall be on uninterruptible and emergency power so they can continue to control through power interruptions.
- Isolation damper closing rates shall be tuned to isolate the lagging system quicker than the leading systems to ensure airflow in the correct direction.
- Differential pressure monitors on critical containment zones shall be provided to indicate the room differential pressure and shall alarm when the pressure goes beyond adjustable thresh-olds and time durations established in concert with the DOHS and the researcher.
- Controllers shall have the capability to automatically restore their volatile memory upon loss of current..
- Damper actuators shall be able to stroke the dampers within 5 seconds for both main systems and terminal systems. Damper fail positions shall be selected to fail in the direction that would maintain pressurization. Fail in last position actuators shall only be used with specific permission.
- Where fireman's override controls are used, the A/E shall consult with the DFM to determine the damper positions when the override mode is activated. They shall continue normal operating positions, but this shall be evaluated on a case by case basis. The fireman's override shall not be able to stop an air system serving a containment barrier or enclosure.

See Chapter 6.HVAC for VFD requirements.

## E.1 BSL3:

All requirements indicated above apply to the BSL3 laboratory except as modified below. The BAS shall provide room pressure monitoring and enunciate alarms when conditions are not normal. The mechanical systems shall include isolation dampers for decontamination. If these are provided with actuators to allow the BAS to actuate them, a decision that shall be made in concert with the Project Officer, provide a key switch to set the position of the dampers from within the suite. Automatic isolation dampers in the exhaust shall fail open. Automatic dampers in the supply shall fail closed if another means is not provided to prohibit reverse pressurization in the time specified below in the event of applicable failures. If the supply automatic damper is not providing this reverse pressure protection, it shall fail open. The position of automated isolation dampers shall be monitored (make on close).

The BSL3 laboratory shall have an anteroom, which shall be passively pressure controlled (controlled to a fixed airflow offset) to create a pressure differential of between -12.5 Pa and -25 Pa and shall also have a room pressure monitor. The exhaust volume shall lead and the supply shall track the exhaust.

BSL3 facilities require multiple levels of room pressurization. Digital differential pressure monitors shall be provided for each pressure controlled zone and shall monitor pressure between each zone and its adjacent reference zone (typically at the entry side of the door to the room per BMBL). Pressures shall be maintained to ensure proper directional airflow between zones.

All controllers in a BSL3 lab area shall provide stand alone capability at the SUITE level. The A/E shall clearly indicate both tracking relationships between air flow terminals and clearly indicate the boundaries of a collection of rooms (suite) that shall be controlled by the same controller. This shall be any given bio-containment boundary/envelope. The A/E shall work with the researcher to analyze the potential for loss of containment due to a controller failure or a controller LAN communication failure and design the controller configuration to minimize risk. Fail positions of the air valves shall be such that containment shall be maintained in the event of failures.

BAS shall monitor HEPA filters when they are provided.

Controllers controlling the HVAC in BSL3 areas shall be primary controllers.

In BSL3 spaces, as the spaces are constructed to have minimal leakage, a cross-limiting loop shall be provided (the control sequence shall automatically reset the flow rate setpoint in the lead terminal box upon detection of excessive flow differential) to restrict the leading system from exceeding the lagging system by a specified value which shall be set to prohibit excessive door opening forces. As an example, if the normal offset is to have the exhaust volume 75 L/s higher than the supply, another control loop shall restrict the exhaust to no more than 150 L/s above the supply. Values shall be set such that the control loops do not interact under normal operation. Cross limiting does not apply to chemical fume hoods, biosafety cabinets, canopy hoods, or other safety equipment.

Pressure control shall maintain space pressures between -12.5 pa and -25 pa. There shall never be a condition in which the control system goes outside this range for more than two minutes and directional airflow must be sustained by drawing air into the laboratory from “clean” areas toward ‘potentially contaminated areas’. The laboratory shall be designed such that under failure conditions the airflow will not be reversed. This has significant implications for the central systems serving the BSL3 area concerning starting, power outage, rotation, and proof logic and hardware. The monitoring requirements of a BSL3 space include:

- Space temperature.
- Space pressure with local indication.

- Alarm conditions and strobe.
- Humidity (where zone level humidity is required only).
- Supply/exhaust velocity (total / static differential) pressure.
- HEPA filter pressure (Refer to Component)(when provided)

A visual strobe shall alarm whenever any given space pressure becomes the reverse of its intended pressure for more than 20 seconds (i.e., when a negative pressure space becomes positive) or whenever the HVAC system fails.

## F. Animal Holding Rooms:

### F.1 All Animal Holding Room:

Animal care shall always take precedence over system component protection. Animal holding rooms shall be controlled to temperature, pressure or directional air flow, and to humidity on a room by room basis.

The monitored points associated with the zone (for zone related equipment requirements, see the applicable equipment) shall be as follows:

- Space Temperature.
- Space Pressure with local indication (where space pressure is controlled).
- Space Humidity.
- Supply Air Humidity.
- Supply Air Humidity for High Limit (if not done with a local limit).
- Air Change Calculation either via terminal flow sensors or flow measuring stations.
- Light level monitoring shall be considered but may be part of a separate system as long as the required AAALAC data is stored.
- Supply/exhaust velocity (total/static differential) pressure.

Individual Room Humidity: Humidity control must be stable. The control system shall maintain humidity within +-5% of set point when the humidifier is being controlled within its limits.

Individual Room Air Changes: On new systems, pressure independent constant volume boxes shall be used to control supply and exhaust flow rates. The DDC system controls modulating dampers in the supply and exhaust to maintain flow rates. The BAS shall monitor both supply and exhaust flows.

For existing systems where installation of pressure independent airflow terminals is not practical, the flow rate into individual rooms shall be maintained by manual adjustments to

balancing dampers. The BAS shall still monitor both supply and exhaust flows. An individual flow probe is required for each individual flow. If there is not sufficient room in the ductwork to measure room flow directly, install multiple sensors and determine flow indirectly by subtracting the resultant multiple flows. If the ductwork is not sufficiently accessible or the flow range is too low for accurate measurement, indirectly determine flow by accurately measuring a suite of rooms and prorating the total suite flow by the known air balance which shall be periodically verified.

Individual Room Pressurization: Individual room pressure is shall be controlled by controlling flow rate at pressure independent terminal boxes. Supply air flow is modulated to either maintain a flow differential between supply and exhaust or to maintain a constant pressure at a room differential pressure sensor. See below for General Pressure Controlled Zones.

Individual Room Space Temperature: Temperature shall be monitored by the DDC system. The location and protection of the sensor shall be coordinated with the animal program. Sensor shall be located in the exhaust duct unless there is not representative location. Provide a high-accuracy sensor. If the sensor must be in the space, the sensors shall be water proof or in a water-proof enclosure and be protected from physical damage from racks. If in the exhaust duct, they shall be located away from direct cage exhaust so that the sensor is representative of the macro-environment and not affected by ventilated rack exhaust blower.

## F.2 ABSL3:

Where Animal Holding Rooms are classified as ABSL3 or above, requirements of BSL3 laboratories apply. The ventilation system must provide sustained directional airflow by drawing air into the animal room from “clean” areas toward ‘potentially contaminated areas’. The animal room shall be designed such that under failure conditions the airflow will not be reversed. This shall include events such as:

- Power outages/transfers.
- Single component failures.
- Maintenance functions.
- Multiple simultaneous component failures that are reasonably probably (for instance fed from a common MCC that does not also feed other systems affecting pressurizations).

Animal Procedure Rooms: Procedure rooms shall be controlled to temperature and pressure. Procedure rooms shall be controlled much the same as indicated for laboratories with the exception that the room shall have a BSC and space differential pressure monitoring shall be standard. See below for control requirements for a BSC. If the BSC is ducted, it

may at times be isolated for decontamination. Controls must maintain suite pressurization while the BSC is being decontaminated. Either provision for an alternate path for the airflow shall be made, or adjustments to adjacent offsets shall be made when the BSC isolation damper is sensed closed.

Cage and Rack Wash Suites: These areas shall be temperature and pressure controlled. The pressurization shall be controlled passively to maintain contaminant flow from clean to dirty areas. Only the space temperature must be monitored.

## G. General Pressure Controlled Rooms:

Many types of occupancies shall require pressure control. Rooms ancillary to other rooms required to be pressure controlled shall need to be pressure controlled themselves to maintain the primary zone. Pressure controlled zones shall sense supply and exhaust airflow. Passive control (supply and exhausts are controlled to a flow set point, with one of the flows slaved to follow the other with an offset) shall be used. Either the supply shall track the exhaust, (where pressure control seeks to keep the space negative), or the exhaust shall track the supply (where pressure control seeks to keep the space positive). This scenario inherently adjusts to potential failures in, or lack of capacity of the main systems. If the leading system begins struggling for any reason, the following system terminal box shall modulate to maintain the offset.

If airflow is not being sensed directly, as in the application of a metering venturi valve, where the flow is being inferred from valve position, a pressure sensor shall be provided on both supply and exhaust systems that alarms when air pressure across the valve is not great enough to keep the valve in range. For non containment systems, if the lead system is in alarm for 2 minutes (enough time for an initial attempt at resetting set points) the system shall be put into a “Distress Mode” such that all pressure zone control set points are reduced to redistribute the lack of capacity in a prioritized fashion. Distress mode shall be alarmed and manually reset.

For BSL3 systems, the lack of pressure shall be alarmed immediately and the distress modes shall be initiated by the pressure sensors provided across the containment barrier.

## H. Principal Investigator (PI) Offices:

PI offices shall be controlled to temperature; and pressure only when integral to the laboratory pressure control. PI Offices shall include a space temperature sensor with local set point override, which shall allow limits applied to the degree of adjustment. These rooms may have a scheduled unoccupied period with local override capability.

## I. Microscope Suites:

The following does not apply to all microscope suites. It may apply to electron, confocal or other types of microscope. This shall apply to highly sensitive types of microscopes. Check with the users before designing.

Sensitive Microscope suites require very “tight” temperature and humidity control. The design of the controls shall be very closely coordinated with the mechanical systems design and the space layout to minimize environmental condition fluctuation across the scope. Either laminar systems or curtains shall be used for this. The typical scope room shall require the following monitoring points:

- Space temperature.
- Humidity.
- Air change calculation either via terminal flow sensors or flow measuring stations.

Humidity requirements shall be coordinated with the scope manufacturer. If the scope uses a gas that could potentially spill and displace oxygen or otherwise create a hazard, a sensor detecting either oxygen or the gas being used will be required to initiate a purge sequence. Controls serving the EM suite shall fail to last position or cooling.

## J. Nuclear Magnetic Resonance (NMR) and Magnet Resonance Imaging (MRI) Suites:

NMR/MRI suites require stable temperature control in the vicinity of the magnets. The design of the controls shall be very closely coordinated with the mechanical systems design and the space layout to minimize environmental condition fluctuation across the magnets. The typical NMR room shall require the following monitoring points:

- Space temperature.
- Humidity.
- Gas detection coordinated with the NMR manufacturer.
- All NMR/MRI rooms require an oxygen sensor to be used to initiate a purge cycle if the magnet quenches.

## K. Computer Rooms:

Computer rooms shall be controlled to temperature and humidity. When the primary control is provided by the BAS, the requirements are listed with the applicable systems and components. Whether completely controlled by the BAS or whether a combination of packaged controls (as would be provided on a computer room unit) and BAS, the ventilation system shall be coordinated with the computer room conditioning system, and the various computer

room conditioning units shall be coordinated to not cause simultaneous heating and cooling (unless required for dehumidification). For instance, the discharge condition of a supplemental OA system for ventilation shall not impose unnecessary humidity (causing cooling and reheat for dehumidification of the computer room units). Humidification control systems shall be coordinated to avoid some systems humidifying while others are dehumidifying. The following at a minimum shall me monitored by the BAS:

- Common alarm on the computer room unit.
- Space Temperature.
- Space Humidity.
- Under floor water if not included in the common alarm.

## L. Environmental Rooms:

Environmental rooms shall be provided with packaged controls. These rooms shall be monitored by the laboratory Equipment Monitoring system not covered in this part of the DRM.

## M. Electrical Vaults:

BAS shall control ventilation in these rooms to maintain acceptable temperature in the spaces. The requirements are listed with the systems and components. The BAS shall include space temperature monitoring and alarming and liquid sensing and alarming

## N. Loading Docks/Shipping and Receiving Areas:

BAS shall control the area to temperature as dictated by the system design. It shall also include a CO sensor to alarm upon high levels of CO and initiate additional ventilation as required by the system design.

## O. Freezer Farms:

In addition to the points required for the HVAC control system, BAS shall monitor the oxygen level in the space and alarm when the level drops below a safe level as specified by OSHA. When emergency exhaust is provided, BAS shall energize the emergency exhaust when the critical level is reached.

## P. Laboratory Corridors:

Laboratory corridors are subject to high traffic and sensors in the space, if used shall be protected and placed in a representative location. Since laboratory corridors are used for pressurization air for the adjacent laboratory zones, and as such, may not have exhaust or return air the alternatives for locating the temperature sensor include 1) in protected representative location, or 2) in the supply air of the terminal supplying this pressurization air. In

the case of the sensor in the supply air, the zone would be set to supply approximately 19°C(66°F).

# Section 7-4: Systems Level Requirements



## 7-4-00 Design Requirements

This section of the DRM describes building systems by the control loops that form the system and how the separate loops work to form the overall system. Systems are composed of components. Many of the requirements of the systems are specified as a part of the component specification. This section indicates requirements of the composite system. The controller for system level requirements shall be powered by the highest level of the power available to any of the components or devices it serves. Specific requirements of the controllers are listed with the system.

The A/E shall coordinate the reliability requirements (with regards to stand alone capability, single sources of failures, and controller level) with the Project Officer and clearly state the requirements in the documents.

## 7-4-10 Design Guidance

### A. Supply Air Handling Systems:

This refers to built up or packaged air systems that have airflows in excess of 1,250 L/s. Terminal units such as fan coil units are indicated below. The requirements for supply air systems are indicated below.

Discharge Air Temperature: All systems require discharge air temperature sensors. Supply air systems serving multiple terminal units, particularly those that serve terminals that involve reheat shall include a supply air reset algorithm. Reset may be based on either outside air temperature or feedback from the terminals. Where control is based on feedback from the terminals, logic shall prevent a single box from controlling the entire system unless it is critical. The reset logic shall be designed to allow dehumidification demand to override heating and cooling demand and vise versa depending on which is greater.

Interface to Fire Alarm System: Systems shall be interfaced with the fire alarm system where required by code. When fireman's override is required, the freeze safety shall be by-

passed (although the basic sequence shall ensure that all coils have full flow in the event of a potential freeze condition). The smoke safety shall remain in affect. The pressure safety shall remain in affect unless it is unlikely that the extreme pressure could render the unit inoperable.

Smoke Control Sequences: Where an engineered smoke control sequence is applicable, BAS may be used to execute the sequences only if it maintains a UUKL 864 certification. Otherwise, the fire alarm system shall locally override all devices via addressable modules.

Controller: Individual air handling units shall be controlled by one single controller with stand alone capability. All programming controlling the components on the air handler shall be contained in a single controller and be provided via one programming language. Only outside air conditions, emergency power indications, and as permitted by the Project Officer terminal based reset parameters may be required across the network. For certified smoke control systems, smoke modes and zone alarms may obviously be allowed over the network. Units serving research laboratory areas, vivaria, BL3 areas, aquatic laboratories, NMR suites, Electron Microscope suites, clean rooms, manufacturing/process facilities, and other areas of commensurate criticality shall be controlled by a primary controller. The A/E shall coordinate the reliability requirements with the Project Officer and clearly state the requirements in the documents.

Humidity Control: Air systems that include humidity control shall include a humidity control sensor and high limit humidity sensor in the supply air duct separated by an adequate distance from the humidifier. If jackets are used on the dispersion tubes of the humidifier, provide an automatic means of isolating the humidifier jacket when the dew point of the outside air is below the applicable set point.

Interlock with Exhaust: Supply air systems that work in concert with exhaust systems shall be interlocked with that system. Exhaust system status is required before the supply air system starts for 100% supply and exhaust systems serving areas that are required to be maintained negative to public spaces.

Start Up and Staging: The BAS shall provide for smooth and orderly start up and staging (where applicable) of the air handling units. The starting of the fan and the opening of associated dampers shall be carefully coordinated. For VAV air handlers, the fans shall start at minimum capacity and ramp up to capacity at a controlled rate. When applicable, end switches on the dampers shall prove damper status before allowing the fan capacity to exceed an unsafe condition and/or exceed a pressure safety setting. Main air to normally open control valves shall not be dropped when the fan is off.

Isolation and Security: Air handlers with outside air capability shall have outside air dampers that shall close when the system is off. Supply isolation and smoke dampers shall be provided as required by NFPA 90. Refer to Security Chapter for requirements of HVAC system control related to security.

Freeze Protection: All AHU's shall have a two pole freeze stat with manual reset. One is required for every 3.7 $m^2$ of coil surface. The freeze stat shall trip when any area of the preheat coil discharge drops below 6ºC. One pole shall be hard wired to the motor starter or drive and the other shall be wired to the DDC panel. When the freeze stat trips, the supply fan shall stop and dampers shall close (unless in fireman's override), and then preheat, chilled water, and reheat valves (for coils within the unit) shall open fully. The freeze stat shall have a time delay relay in the circuit to delay trip for an adjustable time up to 5 minutes and a manual reset which is required to restart the fan and return the freeze stat point to the normal status.

Cabinet and Component Pressure Safety: When the dead head of the fan is capable of damaging the wall, component, or duct associated with the system, upon closure of any isolation or fire damper, the air handler shall be protected with applicable high and/or low differential pressure safety switches with manual reset. Note that given free wheel of the fans, the static pressure safeties can not absolutely guaranty damaging conditions will not be experienced. Therefore, the A/E shall provide for protection of system components in the event abnormal conditions develop (e.g.: relief panels).

Scheduling: When feasible in areas that are not occupied at all times and where code permits, the control sequence shall incorporate scheduling and setback to minimize energy use.

Supply Air Pressure Control: A sensor that is at about 2/3 the length of the supply main or a location that is representative of the system pressure shall monitor supply air pressure. Supply pressure shall be controlled to maintain a set point that allows optimal control with minimum energy consumption.

Headered Systems: Headered systems are those that have multiple air handlers or fans feeding a common supply distribution system. Critical systems in the following refer to systems serving fume hoods, BSCs, vivaria, and containment and high containment systems:

- The BAS and/or a local controller shall be capable of selecting any of the headered fans as the lead fan and shall select one of the headered fans as the lead fan.
- When starting a fan controlled by a VFD, fan shall be started into a closed damper to equalize the pressure up and downstream of the damper and prohibit backspin of the

fan. When the speed of the fan crosses a threshold speed (indicating “fan running”) and static pressure proves fan operation, isolation dampers shall be opened. End switches on isolation dampers shall limit the speed of the fan to a safe preset condition but near the typical header operating pressure. When the damper end switches indicate an open damper, VFD shall allow acceleration of the fan beyond the preset condition. The VFD shall command open and closed the motorized isolation damper.

- Control system shall control all operating fans (of equal capacity) on a header to a common speed. The network can be used to coordinate the speed of the fans, however, the controller shall revert to a local control loop in the event of loss of network communication. Upon loss of com, an operating fan shall continue to operate and revert to its local loop or maintain the last known command. If the fan is not operating at the point when com is lost, it shall remain off until com is restored and it is commanded to run.
- The lead shall be rotated automatically.
- The lead rotates automatically upon failure of fan. On scheduled rotation, the lag shall start and prove status before the stopping fan is stopped.
- Anytime a fan fails or a start-up sequence fails, the BAS shall generate an alarm and the alarm status shall continue until manually reset even if subsequent attempts at start-up succeed. When the fan fails or the start sequence fails, isolation dampers shall be commanded closed, and the BAS shall initiate one retry to start the fan. If the fan again fails to start, the BAS shall initiate a start sequence on a back-up fan. If back-up fails to start after two start tries, the BAS shall repeat attempting to start one fan and then the other until one starts or the fan sequence is manually overridden.
- For critical systems, extra fans on a manifold/header shall be run continuously at a lower speed and when one fan fails, it shall be isolated, the BAS shall generate an alarm, and the other fans shall speed up to meet the system set-point pressure.
- VFD’s shall be controlled directly by the BAS controller via hard wired interface, not across the control LAN through manufacturer provided controllers that are integral to the VFD.
- Status shall be proved by current switches. Switches sensing proof on critical systems shall be capable of sensing a loss of status due to a belt break, as well as any other loss of status) in 10 seconds. The application shall be analyzed by the A/E to assess if the minimum preset run speed shall create enough amp draw to exceed a no load motor amp draw at 60 Hz (broken belt scenario). If a reliable current switch amp setting can not be determined based on the application, proof logic shall be supplemented with either pressure switches or drive logic.
- On headered systems that may result in higher than design airflows during a condition like failure of another fan on the header, the BAS shall limit the operating fan speed to a safe volume that shall not result in excessive filter forces or water carryover from a condensing cooling coil.

Airflow Monitoring: Supply airflow shall be monitored by the BAS on all systems above 5,000 L/s.

Supply Systems BSL3 Laboratories: For systems serving BSL3 laboratories, ensure the following:

- Status indication to be used in failure and restart logic shall consistently indicate change in status within 10 seconds. Status indications shall further be capable of distinguishing belt breaks from normal operation at minimal load. Either current switches with the intelligence required and speed of response, standard current switches applied to systems where the minimum operating amp draw shall exceed that of the no load motor at 60 Hz, or differential pressure switches are acceptable. Upon a supply fan failure, either a redundant supply fan shall start, or if the redundant fan is running, then it shall ramp up. If ramp up is not achieved or there is not a redundant fan, the exhaust fans shall be ramped down to maintain a differential pressure -12.5 to -25 Pa, or shut down.
- Central system controllers shall also be on uninterruptible and emergency power, and must detect power interruptions and take appropriate action locally. This in effect means providing a three phase monitor as an input to the controller.
- Isolation damper closing rates shall be tuned to isolate the lagging system quicker than the leading systems to ensure airflow in the correct direction.
- Pressure cutout switches shall be tuned to trip the unit when extended beyond normal pressure but shall have adequate delay to avoid nuisance trips due to short transient excursions. Trips from excessive pressure shall be manually reset.
- Controllers shall have the capability to automatically restore their volatile memory upon loss of current.
- Damper actuators shall be able to stroke the dampers within 5 seconds for both main systems and terminal systems. Damper fail positions shall be selected to fail in the direction that would maintain pressurization. Fail in last position actuators shall only be used with specific permission.
- Where fireman's override controls are used, the A/E shall consult with DFM to determine the damper positions when the override mode is activated. They shall continue normal operating positions, but this shall be evaluated on a case by case basis. Fireman's override shall not be able to stop an air system serving a containment barrier or enclosure. The laboratory ventilation system must continue to provide directional airflow.

## B. Stairwell Pressurization Systems:

When required by code or a performance based fire protection design, building systems shall include a stairwell pressurization system. This shall be initiated by the fire alarm sys-

tem whenever an alarm condition occurs. BAS shall monitor the command and status of the fan and enunciate an alarm when status does not match command

## C. Exhaust Air Systems:

### C.1 All Exhaust Air Systems:

The following is required for exhaust air systems that have air flows in excess of 1,250 L/s. The requirements are indicated below.

Interface to Fire Alarm System: Systems shall be interfaced with the fire alarm system as required by NFPA and the authority having jurisdiction. As required, the operation of the fans and dampers shall be controllable by the fire alarm command center. If the building is not equipped with a fire command center, the manual controls for the fans and dampers shall be located per direction of the fire protection authority having jurisdiction. Where the DFM has jurisdiction, fume hood exhaust systems remain in operation during fire scenarios.

Smoke Control Sequences: Where an engineered smoke control sequence is applicable (these shall not be used at NIH even on high rise buildings), BAS may be used to execute the sequences only if it maintains a UUKL 864 certification. Otherwise, the fire alarm system shall locally override all devices via addressable modules.

Controller: Exhaust systems shall be controlled by one single controller with stand alone capability and all programming shall be provided via one programming language. Units serving research laboratory areas, vivaria, BL3 areas, aquatic laboratories, NMR suites, Electron Microscope suites, clean rooms, manufacturing/process facilities, and other areas of commensurate criticality shall be controlled by a primary controller preferably the same as controls the supply (this shall be limited by size).

Interlock with Supply: Exhaust air systems that work in concert with supply systems shall be interlocked with that system. Exhaust system status shall be required before the supply air system starts for 100% supply and exhaust systems serving areas that are required to be maintained negative to public spaces. Exhaust systems shall be required to have their output limited until supply system status is indicated so as not to create an excessive negative pressure. This shall be done where possible at the terminal level.

Up and Staging: The BAS shall provide for smooth and orderly start up and staging (where applicable) of the exhaust fans. The starting of the fan and the opening of associated dam-

pers shall be carefully coordinated. For VAV exhaust systems, the fans shall start at minimum capacity and ramp up to capacity at a controlled rate.

Isolation: Exhaust systems shall be provided with automatic dampers to close and isolate the system when the system is off.

Component Pressure Safety: When the dead head of the fan is capable of damaging one of the components, or duct associated with the system, upon closure of any isolation or fire damper, the system shall be protected with applicable high and/or low differential pressure safety switches hard wired to the starter circuit. Note that given free wheel of the fans, the static pressure safeties can not absolutely guaranty damaging conditions will not be experienced. Therefore, the A/E shall provide for protection of system components in the event abnormal conditions develop, (e.g.: relief panels).

Scheduling: When feasible in areas that are not occupied at all times and where the code permits; the control sequence shall incorporate scheduling and setback to minimize energy use.

Headered Systems: Headered systems are when multiple air handlers or fans feed a common supply distribution system. Refer to Supply Air System Headered Systems item. The same applies to the exhaust.

Airflow Monitoring: Exhaust airflow shall be monitored by the BAS on all systems above 5,000 L/s.

Security: A/e shall include design provisions for requirements of HVAC system control related to security.

Fume Hood and BSC Exhaust Air Systems: Systems that exhaust fumes from laboratory fume hoods shall be designed and controlled to maintain transport velocity in the ductwork. This shall be coordinated with the system design. See also Exhaust Air Stacks in the Contaminated Systems section. Sensors for fume hood systems shall be selected for corrosion resistance and for the appropriate hazard in the duct. Control sequences shall start these systems first when restarting after failures and power transfers. Dampers in these systems shall fail open.

Exhaust Systems Serving BSL3 Laboratories: See Supply Systems in Chapter 6, for requirements that apply to the exhaust system as well.

## D. Building Steam Connections to Campus System:

This item refers to extensions of the plant steam into various facilities. Refer to the Building Level section of the DRM for the steam service metering and main condensate system requirements. The BAS shall monitor each pressure stage at the header and have alarms set for them.

## D.1 Modulating Steam Valves:

Modulating control valves selected for steam heating shall be sized for good control. They shall have a linear characteristic and be sized for a pressure drop of approximately 75% of the supply steam pressure. If steam modulation is used as the only means of capacity control, two valves shall be provided in a 1/3 – 2/3 arrangement to improve controllability. One BAS output may be used for both valves provided ranges on valves are carefully coordinated. Control loops shall be tuned at light load and checked under heavy load.

## E. Clean Steam (Steam Source Boiler) Systems:

BAS shall monitor and alarm (high and low) the pressure produced by the boiler. BAS shall also alarm on both high and low water level conditions in the steam drum/vessel. When packaged controls are provided, the BAS shall also monitor an overall alarm condition point from the packaged controls. When the BAS controls the systems, the requirements shall be specified with the components.

Make up water shall be preheated for these systems to improve level control. When this is the case and the pre-heaters are controlled by the BAS, the status of flow to the system shall be monitored by the BAS to enable/disable feed water control based on water flow. Modulating make up controls shall provide a more stable system and are recommended.

Clean steam systems shall control an automatic surface blow down to purge the system of solids. Control may either be timed or be continuous and controlled by a conductivity controller.

## F. Hydronic Systems:

## F.1 All Hydronic Systems:

Most of the requirements of hydronic systems are covered in the components that make them up. At least one key point of static pressure shall be monitored and a low alarm shall be set at the point when any valve will be struggling to maintain its required flow. Additionally, the supply and return temperatures shall be monitored on all systems. Flow shall be monitored on most systems however, exceptions may be granted by the Project Officer where there is no value for diagnostic monitoring or measurement and verification.

The control sequence for the hydronic loops shall control the source component(s) to maintain a supply temperature that is reset when this is feasible for the system being served. Guidance on reset strategies are include with specific systems.

If, redundant heat exchangers on cooling systems are provided, they may simply remain active all the time. On steam source heating components however, the minimum required heat exchange surface shall be active at any time. This shall require automatic isolation of the various converters.

When hydronic systems include redundant or staged pumps, the sequence shall provide for automatic start of the back up pump on failure, stopping the back up pump when it is no longer needed, rotation of the lead device, as well as maintenance lock out.

The A/E shall designate systems that require control by a primary controller. Typical systems that shall require primary controllers will be systems that serve critical spaces or many spaces such that the expense is justified.

## F.2 Steam to Water Hydronic Systems:

Controls shall facilitate automatically isolating flow from the converter(s) that are not needed for capacity such that the control loop gain is reduced and therefore easier to tune. This shall mean a single two position valve shall be provided on the water circuit to each converter when one is redundant. Automatic sequencing of the backup component, as well as rotation of the lead and maintenance lockout shall be included in the sequence. Reset strategies for heating systems shall be as follows:

- Reset shall be based on terminal requirements when the terminals are controlled by the BAS, the quantity is manageable, and the terminals are dedicated to one secondary controller LAN or primary controller.
- Reset of perimeter systems that do not incorporate terminal reset shall be based on outside air temperature.
- Reset for dedicated glycol preheat systems shall be based on outside air temperature.
- No reset is required for systems serving reheat coils except as modified below.

## F.3 Chilled Water Hydronic Systems:

Campus Chilled Water Connections: The control of the plant chilled water connection for new facilities shall be carefully coordinated with the design and site utility requirements through the Project Officer. The connection and controls shall be designed to maximize the facility's temperature differential and to maximize reliability and avoid adverse impact on the distribution system pressures and temperatures. Regardless of the connection configura-

tion, the building chilled water control valve shall be selected for high turn down ratios and good control across significant plant pressure differentials. The A/E shall specifically present an analysis predicting the valve flow versus percent stroke on the specified valve at various plant differentials. Building valve shall be normally open. Multiple staged valves may also be used to improve control. On the system (campus) side, the following shall be monitored:

- Supply temperature.
- Return temperature.
- Supply pressure.
- Return pressure.
- Flow rate.
- Control valve position.

On the load side (building side of bridge), the following shall be monitored and where appropriate, controlled:

- Supply temperature.
- Return temperature.
- Pump speed.
- Flow rate.
- System differential pressure.

The building supply temperature shall be controlled based on a reset offset from campus supply temperature (for instance campus plus 2 in warm weather reset to campus plus 5 in cool weather) to maximize differential temperature on the campus side while meeting critical cooling and dehumidification load requirements on the building side.

Stand Alone Chilled Water Plant: In facilities where a chilled water plant is provided, control coordinating the operation of the overall plant shall be done with a primary controller. The details of the control of a stand alone plant are not covered by the DRM.

Process Cooling Water Systems: Process cooling systems shall be controlled by a primary controller. Upon plant chilled water failure, the BAS shall sound an alarm and automatically shift the systems to the alternate cooling source (i.e.: domestic water or dedicated cooling tower). Back up cooling source shall also be controlled to maintain process cooling supply temperature. To revert back to plant chilled water shall require manual acknowledgement.

The A/E shall carefully select the domestic water and chilled water isolation valves to ensure adequate close off pressures.

Run Around Heat Recovery Systems: Run around heat recovery systems shall be designed and controlled to maximize the energy efficiency of the system. Heat recovery system controls shall be powered from the same source as the systems that contain them. Four modes of operation shall be used:

- Winter Mode: Winter mode shall be when the outside air temperature is below the supply air set point minus 3ºC. Pump shall run and flow shall be modulated to maintain the supply air temperature leaving the heat recovery coil at a set point coordinated with the other loops in the supply system.
- Intermediate Mode: This mode is when the outside air temperature is above the supply air set-point and below the return/exhaust air temperature plus an offset to adjust for the cost of running the pump vs. the recovered heat. In this mode, the pumps shall be off.
- Summer Mode: When the outside air temperature is above that indicated for the high side of the intermediate range, the pumps shall run at maximum capacity and the flow shall be maxi-mum.
- Anti-Frost: When the Heat recovery water entering the exhaust coil falls below 3ºC, supply air coil water flow shall be throttled to maintain that temperature above 0ºC.

If a steam to hot water convert is used to inject heat into a heat recovery loop to form a combination heat recovery and preheat system, the converter leaving temperature shall be controlled to maintain the preheat air temperature at an offset of slightly below the preheat air temperature set point such that one valve shall be fully open and its loop shall be lacking before heat is added to the loop. When preheating load falls and recovered heat is sufficient, the heating set point shall be lowered to avoid unnecessarily adding heat into the loop.

## G. Domestic/Industrial/Laboratory Water Systems:

Refer to Building Level for service requirements. When systems include booster pumps and packages, BAS shall monitor the supply pressure and temperature as well as a common alarm on the booster pump package (the assumption being that the booster system includes packaged control)

## H. Control Air Systems:

Control air systems shall include a pressure sensor to monitor supplied control air pressure. Alarms shall be established for low pressure conditions that will have an impact on BAS control.

Where a packaged control system is used, the BAS shall monitor a common alarm from the compressed air skid. The BAS shall also monitor a common alarm from the air dryers.

## I. Drainage and Waste Systems:

Where drainage system include sump pumps or lift stations, BAS shall at a minimum include level switches to monitor the high sump/basin level. Where the BAS controls the systems, (when they are not furnished with packaged controls) BAS shall control the components of the systems.

Where the drainage system includes a neutralization system with packaged controls, BAS shall at a minimum monitor a common alarm from the packaged controls. PH levels shall be alarmed as part of the complete application. If the packaged system alarms on pH excursions, the BAS monitoring of the common alarm will suffice. Where no alarm is provided on the packaged system for pH excursions, the BAS shall include an analog pH sensor and alarm upon excursions beyond the ranges dictated by the applicable DRS (for example below 6 or above 10).

For containment and high containment applications, the BAS shall monitor a common alarm from any Effluent Decontamination systems. The BAS shall monitor the effluent temperature and alarm upon effluent temperatures above 60 ºC when the effluent decontamination is done with heat.

## J. Laboratory Air Systems:

BAS shall monitor and alarm the supply pressure to the system as well as the dew point. The BAS shall also monitor the common alarm from the packaged sequencing controls. See the Building Level section of the DRM for plant air service monitoring. BAS shall also include a high differential pressure switch alarm on the main supply air filter (the physical DP may be included with the system package but the alarm shall be indicated on the BAS).

## K. Breathing Air Systems:

BAS shall monitor pressure on the breathing air system manifold downstream of any filters, check valves, or reducing stations. BAS shall alarm on low or high system pressure. BAS shall monitor the status of the primary system and enunciate an alarm when the air system reverts to back up air supply. BAS shall monitor the supply pressure of both the primary air supply manifold and the back up system supply air manifold and alarm on low pressures. A packaged air quality monitor shall be provided by the breathing air system supplier. BAS shall monitor a common alarm from that air quality monitor system. All alarms on the breathing air system shall be enunciated at applicable monitoring locations within the facility as well as in the zones fed by the breathing air system.

## L. Vacuum Systems:

BAS shall monitor and alarm the main vacuum system. The BAS shall also monitor the common alarm from the packaged sequencing controls. Where HEPA filters are in place for containment and high containment applications, BAS shall monitor and alarm differential pressure across the filter.

## M. Fuel Oil Systems:

BAS shall monitor the level in any primary storage tanks (not day tanks). BAS shall alarm in the case of a spill or any containment breach. BAS shall alarm in the case of transfer pump failure and or over temperature. Frequently these alarms can come from an interface to packaged transfer pumping or level and leak monitoring systems specified with the equipment. When the transfer pumping is controlled by the BAS, the requirements are specified with the components.

## N. Emergency Power Systems:

See the Building Level requirements for the emergency service monitoring requirements. The status of the emergency power feed on the transfer switches shall be monitored and indicated on a graphic in the BAS (at a minimum the transfer switches that serve mechanical equipment shall be monitored). This emergency position status monitor shall be provided directly to a primary controller. Careful consideration shall be given to the propagation of that information to controllers as they reboot from a power interruption. This may require certain critical controllers to be powered from uninterruptible power to ensure rapid propagation of the emergency status.

Consideration shall also be given to anticipating power transfers to allow systems to be commanded to a controlled stop before transfer to avoid the potential of unpredictable behavior on short duration outages. Monitoring of only the fact that transfer switches are in the emergency position will not suffice for this. The A/E shall carefully coordinate the interface between the transfer switch or SCADA controlling the emergency power system and the BAS.

## O. Centrally Stored Laboratory Gas Systems:

BAS may monitor packaged controls on these systems for common system alarms if requested by the institute and agreed to by ORF in writing. These alarms shall be enunciated on the BAS. In some cases, laboratory gas systems are owned and operated by a scientific program and not part of the BAS.

## P. Desiccant Dehumidification Systems:

Desiccant dehumidifiers for specialty laboratories may come under the jurisdiction of ORF or the institute. The A/E shall verify. BAS shall monitor at a minimum the discharge temperature, discharge humidity of conditioned air, entering and leaving process air temperature, space humidity that is the primary control variable for the system, and common alarm on packaged control systems. High and low alarms shall be configured for discharge temperature, discharge humidity of conditioned air, and space humidity. In cases where desiccant dehumidifier is dedicated to a program, it shall not be monitored by the BAS.

## Q. Uninterruptible Power Supply Systems:

BAS shall monitor these systems. Monitoring shall include basic status, common alarm, and battery voltage. In cases where uninterruptible power systems are dedicated to a program, it shall not be monitored by the BAS.

# Section 7-5: Component Level Requirements



## 7-5-00 Design Requirements

The following lists BAS requirements by component. These components are those that make up the systems that serve facilities at NIH. BAS devices are not to be duplicated if two requirements indicate the same application.

## 7-5-00 Design Guidance

### A. Fans:

### A.1 Fans Controlled by Starters (w/Associated Isolation Dampers):

A HAND-OFF-AUTO (HOA) switch shall be provided in the starter of the fans. Any applicable fireman's override shall override any HOA switch function. Otherwise, the HOA shall control the fan as follows: In the hand position, the fan shall start and run continuously unless a safety device trips; in the off position, the fan shall stop; in the auto position, the BAS shall control the fan as indicated below.

BAS shall control starting and stopping of the fans. Fan starting shall be coordinated with any associated isolation damper; only starting (or accelerating beyond a safe speed in the case of headered systems) after the damper is open far enough to not damage the system or trip a pressure safety. If at any time during the fan operation the damper open indication is lost, the fan shall be de-energized. On headered systems, isolation damper opening shall be coordinated to prevent back-flow to the extent practical.

Status shall be monitored via the appropriate type of current switch and BAS shall prove operation. BAS shall enunciate a "fan failure" alarm whenever the fan is commanded to run and status is not proved within an adjustable debounce time. BAS shall enunciate a "Hand Operation" alarm when the fan is commanded off and on status is indicated. In the "fan failure" mode, the on command shall remain except on headered systems where it will be switched to stop and isolation dampers closed to prevent backflow. In no case shall a loss of status coincident with a loss in power be alarmed as a failure.

Where fan capacity is modulated by mechanical means such as inlet vanes the BAS shall modulate the capacity device in response to the system static pressure sensed at a location(s) remote from the fan. The location of the remote sensing device shall be indicated by the A/E on the design documents and the final location shall be identified on the record control drawings. The set point shall be reset based on terminal requirements when practical (this will not be practical when serving VAV fume hoods for instance because the terminal requirements vary too rapidly). Programming shall be in place to avoid one terminal device driving the entire system unless it is critical. Points required for fans and dampers are (as applicable):

- System Start/Stop (BO).
- Fan Status (BI).
- Remote Static Pressure (AI).
- Damper End Switch (BI) when required to avoid system damage.
- Capacity Device Modulation (AO).
- Differential Pressure (local switch) (when required).

## A.2 Fans Controlled by Variable Frequency Drives (w/Associated Isolation Dampers):

See the Variable Frequency Drive Component for more requirements relative to drives. An HOA switch shall be provided on the VFD. Any applicable fireman's override shall override any HOA switch function. Otherwise, the HOA shall control the fan as follows: In the hand position, the fan shall start and run continuously at a speed manually set on the drive unless a safety device trips. A mechanism shall be provided to open the dampers when the HOA is in the hand position. In the Off position, the fan shall stop and dampers shut. In the auto position, the BAS shall control the fan as indicated below.

The drive may have a drive bypass. Bypass position shall be monitored and enunciated as an alarm on the BAS. When the drive is in bypass position, the isolation damper end switches shall be in the safety circuit. That contact shall be shunted when the drive is in the Drive position.

BAS shall control starting and stopping of the fans. Fans shall start at minimum speed and ramp up under a controlled rate to the required capacity. When fans stop, they shall ramp down from control speed to minimum at a controlled rate prior to stopping.

The starting and ramp up shall be coordinated with the opening of any isolation dampers when there is a potential for damage or a pressure safety trip. This coordination shall be one of the following:

- STAND ALONE: Only energize the fan when the damper end switch indicates that the damper is open far enough to not cause physical damage or trip a pressure safety. If at any time during the operation of the fan the damper open indication is lost, the fan shall stop immediately (not under the controlled rate).
- HEADERED: Energize the fan to a preset minimum speed that will not do any damage to the system and equalize the pressure in the common duct. Upon indication that the damper is open far enough not to do damage, the fan shall be allowed to accelerate to required speed. If at any time during fan operation the damper open status indication is lost, the fan shall decelerate to the preset speed under the control of the drive.

Status shall be monitored via the appropriate type of current switch (either provided separately or within the drive) and BAS shall prove operation. BAS shall enunciate a “fan failure” alarm whenever the fan is commanded to run and on status is not proved within an adjustable debounce time. BAS shall enunciate a “Hand Operation” alarm when the fan is commanded off and status is indicated. In the failure mode, run command shall remain except on headered systems for which the run command shall be removed requiring manual acknowledgement before restart.

Drives configuration shall include the following:

- Automatic restart on power interruption.
- Acceleration and Deceleration rates appropriate to the application.
- On critical applications, drive shall start into a freewheeling fan and accelerate or decelerate to the required control frequency without stopping or going to a minimum speed first.

BAS shall modulate the drive in response to the system static pressure.

When the speed feedback does not match the command with an adjustable tolerance for more than an adjustable time delay, the BAS shall alarm a “drive override” alarm:

Point required for fans and dampers are:

- System Start/Stop (BO).
- Fan Status (BI).
- Pressure Sensor (AI).

- Common Drive Alarm.
- Drive in bypass (BI).
- HOA position (BI's).
- Damper End Switch (BI) when required to avoid system damage.
- Speed Control (AO).
- Speed Feedback (AI).

## B. Variable Frequency Drives (VFD'S):

### B.1 Variable Frequency Drives General:

The BAS shall provide for seamless integration with the control of variable speed drives and associated systems. Interface may be either hardwired (point by point wiring to an applicable terminations on the drives interface board), or through digital communications via a controller LAN (i.e.: a Siemens P1 chip included with the drive or a Modbus interface to the drive), or a combination of both. See below for critical applications. When the communications option is provided, appropriate protections shall be programmed for communication failures. For instance, if communication is lost from the drive controller, the BAS shall assume the unit has failed and respond accordingly. In such case, the damper end switches and safeties shall be wired to the drive for safe local operation. If the drive controller loses communication with the unit controller, the drive shall shut down the fan.

For air system applications, all safety indications shall be appropriately wired to facilitate seamless operation. The control system shall in all cases recognize when the drive is operating, even if the drive is in hand operation via the drive panel and execute the programmed sequence of temperature control.

### B.2 VFDs In Critical Applications:

Room pressure critical areas include BSL3 and any others identified as critical during the planning. The following applies to these areas:

Interface between the BAS controller and VFD shall be hardwired directly, point by point from the BAS to the VFD interface board. Interface shall not be done through digital communications except as provided supplementary to the hard wired interface.

## C. Pumps:

An HOA switch shall be provided on either the starter or the VFD. HOA shall control the pump as follows: In the hand position, the pump shall start and run continuously; in the off position, the pump shall stop; in the auto position, the BAS shall control the pump as indicated below.

BAS shall control starting and stopping of the pump. Pump shall start at minimum speed and ramp up under a controlled rate to the required capacity where variable flow is used. When pump stops, it shall ramp down from control speed to minimum at a controlled rate prior to stopping.

Status shall be monitored via the appropriate type of current switch (either provided separately or within an associated drive) and BAS shall prove operation. Status must be valid whether the drive is normal or in bypass. BAS shall enunciate a "pump failure" alarm whenever the pump is commanded to run and status is not proved within an adjustable debounce time. BAS shall enunciate a "Hand Operation" alarm when the pump is commanded off and on status is indicated. In no case shall a loss of status coincident with a loss in power be alarmed as a failure. Drives shall have automatic restart programmed.

Where pump capacity is modulated by a speed drive, BAS shall modulate the drive in response to the system static pressure sensed at a location(s) remote from the pump. The set point shall be reset based on terminal requirements when practical. Programming shall be in place to avoid one terminal device driving the entire system unless it is critical. When the speed feedback does not match the command with an adjustable tolerance for more than an adjustable time delay, the BAS shall alarm a "drive override" alarm.

Points required for pumps are:

- Pump Start/Stop (BO).
- Pump Status (BI).

With Veda's additional points are:

- Speed Control (AO).
- Speed Feedback (AI).
- Common Drive Alarm.
- HOA "Not in Auto".
- Drive in Bypass.

## D. Coils (in AHU's over 1,500 L/s):

### D.1 All Coils:

Coils shall be controlled by a modulating valve and include a temperature sensor immediately downstream of the coil before any other coil or heat transfer element. Coil selection shall be coordinated with the control design and valve selection to ensure stable control particularly at light loading conditions. Therefore the minimum number of points shall be:

- Capacity Control Valve (AO).
- Leaving Air Temperature (AI).

When heating and cooling coils are included in one supply system, programming shall prohibit simultaneous heating and cooling operation (unless required for dehumidification) and smoothly sequence as loading changes. Coil control programming shall be coordinated with all other elements that affect temperature of the supply air to minimize the energy use.

Refer to the BAS Hardware section of the DRM for valves and sensor requirements. Sensors within an air handler shall be averaging unless they are after a well mixed condition like downstream of a fan.

### D.2 Preheat Coils General:

All preheat coils shall be controlled from the coil leaving temperature (the set point of which shall be dynamically adjusted to coordinate with other loops). Preheat control valves shall be normally open when used for general heating and shall be normally closed when serving systems such as vivaria. Preheat control shall remain active when the unit is de-energized therefore it can not be fed from the same air that powers the dampers. In addition to the minimum points required for all coils, preheat coils shall have a low limit temperature sensor.

Steam Preheat Coils: Steam preheat coils where they are the only means of modulating capacity are not recommended, however, in the case they are used, the steam input shall be controlled by two valves with a 1/3-2/3 arrangement. Control valves shall be sized for a pressure drop of 75% of inlet pressure.

Where face and bypass dampers are used, provide at least one valve sized for modulating service above 5°C (40°F). The sequence shall include opening the face damper to full face and modulating the referenced valve above 5°C (40°F) to minimize wipe-off overheating. Below, 5°C (40°F), the steam valves shall be full open and the face and bypass dampers

shall be modulated for control. Ensure sensors and freezestats are adequately downstream of the face and bypass dampers to get a good mixed condition.

Glycol Preheat Coils: Valves shall be sized for good control across the range. Glycol supply temperature to the coil shall be reset with outside air such that the required flow shall stay in the turbulent region on the coil. Alternatively, a coil recirculating pump may be provided that shall maintain flow in the turbulent region at low loads and based on outside air to ensure freeze protection.

## D.3 Chilled Water Coils:

Chilled water coil selection shall be coordinated with the control design to ensure smooth operation and stable control at low load, particularly with 100% OA units. If feasible, reset the chilled water temperature to keep the flow in the turbulent region. As this may not be feasible if some units are dedicated to internal zones, provide an alternate means of ensuring adequate flow at low load. Chilled water valves shall fail in a position based on the application:

- Chilled water valves serving 100% outdoor air units shall fail open.
- Chilled water valves serving computer rooms or other spaces that primarily need cooling shall fail open.
- Chilled water valves serving recirculating systems, which in turn serve standard occupied zones shall be normally closed.

## D.4 Reheat Coils:

Reheat coil valves shall be sized for smooth and stable control. . Reheat valves on reheat coils provided with the supply air handler shall close when the system is off. Actuators on the reheat shall fail in a position as is applicable for the space it serves. For specialty rooms, consult with the researcher as to the potential for harm in either case. Examples are:

- General space reheat valves shall fail in the last position or open.
- Animal holding room reheat valves shall fail in the last position or closed (and room shall have high temperature alarm).
- Computer room reheat valves shall fail closed.

For most terminal applications, a floating type electric actuator will be acceptable such that timed recalibrations are required. However, these shall not be permitted in critical applications unless it can be demonstrated that the recalibration will not result in temperature

swings beyond the space temperature tolerance. The following occupancies shall not include floating reheats without approval of the Project Officer:

- Animal holding rooms.
- Containment and high containment laboratories.
- NMR suites.
- EM suites.
- Procedure rooms.
- Isolation rooms.
- Any other application requiring tight temperature tolerances.

## F. Converters:

Steam converters shall be controlled by properly sized steam valves in a 1/3 – 2/3 arrangement. When redundant converters are provided, provide automatic ability to isolate the redundant converter. Control shall be based on leaving heating water temperature, reset when feasible with systems served as indicated for Hydronic Systems. Points required for a typical converter are (note that return temperatures are required at the system level):

- Enable (BO) when multiple converters are provided.
- Capacity Control (AO) to staged valves.
- Discharge Temperature (AI).

Steam valves for the converter shall fail closed. In some cases, the converter may be part of scientific equipment and any connection to the BAS shall be at the request of the institute.

## G. Heat Exchangers Fluid-to Fluid:

Heat exchanger shall include a modulating control via a properly sized valve and control of heat exchanger shall maintain system supply temperature. Points required for a typical heat exchanger are (note that return temperatures are required at the system level):

- Enable (BO) when multiple heat exchangers are provided and automatic isolation is required.
- Capacity Control (AO) to staged valves.
- Discharge Temperature (AI).

## H. Mixed Air Section and Associated Relief:

Mixed air sections are not covered in the DRM.

## I. Humidifiers:

Humidifiers shall be controlled to maintain the space or exhaust/return duct humidity, and/or a maximum supply duct relative humidity of 85%. As such, the BAS shall include space or exhaust/return duct humidity, supply duct humidity, and capacity control (coordinated with the designed humidifiers however modulating).

For jacketed humidifiers that keep the dispersion tubes heated, the BAS shall include a two position isolation valve on the humidifier steam that is opened below an applicable outside air dew point temperature and closed above it with an acceptable dead band.
Exercise care in placing sensors and other components downstream of a humidifiers to make sure they are well past the absorption distance.

When the humidifier is a packaged system such as a re-boiler, BAS shall monitor a common alarm. Care shall be taken in applying local packaged reboilers with regards to the continuity of steam pressure during fill cycles. Fill cycles with cold water can depress steam pressure in the dispersion header and cause the control loop to wind up resulting in overshoot when the fill cycle stops. This can cause saturation of downstream surfaces and potential tripping of downstream smoke detectors. Coordinate with the mechanical design to ensure this situation is avoided.

## J. Exhaust Air Ducts:

Sensors in exhaust ducts shall be able to withstand the exhaust environment and be rated for any applicable hazard. Exhaust air ducts shall include the following points as qualified:

- EA Temperature (AI) only for systems that include general exhaust.
- EA Humidity (AI) when system level humidity is controlled or the zone requires humidity monitoring.
- Smoke Detector (local device) as required by NIH and NFPA (See the DRM Appendix A for application of Smoke Detectors on Bethesda Campus).
- Pressure sensors when required by system the duct is a part of.

## K. Filter Racks (Including Pre, Final, and HEPA):

BAS shall monitor the differential pressure status of the filter bank. A differential pressure switch shall make when the differential pressure across each bank of filters exceeds the loaded condition associated with the rated flow on the unit. A differential pressure gage shall also be mounted in parallel with each switch.

A pressure sensor (AI) shall be used in lieu of a pressure switch on all HEPA filter banks. Care shall be taken to filter the contaminants in the dirty sensing line to keep the sensor

clean. Provisions shall also be made to decontaminate and remove the sensing line HEPA filter.

## L. Exhaust Air Stacks (Contaminated Systems):

The velocity of the exhaust air in exhaust stacks shall be controlled to maintain adequate dispersion and to prevent entrainment in outside air systems. When systems are constant volume, no monitoring is necessary. When systems are VAV, bypass air is used to maintain the stacks at constant volume, no monitoring is necessary. However, if the minimum velocity is maintained by staging systems or any means where the velocity in the stack varies, airflow velocity sensor shall be provided if the velocity can not be calculated from measured airflow. Single point sensors positioned and calibrated shall be adequate for this.

## M. Heat Recovery Wheels:

BAS shall fully control heat recovery wheels including sensing the temperature of all four air streams around the wheel, and the speed of the wheel via the speed drive furnished with the wheel. BAS shall also monitor the rotation sensor and alarm when rotation is expected and not proven. Heat recovery sequence shall be coordinated with all other thermal and humidity loops in the air systems. Mechanical design and the controls shall be provided to enable the wheel to be isolated from any air stream for maintenance. Averaging temperature sensors shall be used downstream of the wheel where space is not provided to allow adequate mixing as is typical on the supply side. Adequate mixing distance shall be provided before a single point sensor to ensure thorough mixing.

Heat wheel sequence shall include the following modes:

- Winter Mode: Winter mode shall be when the outside air temperature is below the supply air set point minus 3ºC. Speed of the drive shall be modulated to maintain a the supply temperature leaving the heat recovery coil at a set point coordinated with the other loops in the supply system.
- Intermediate Mode: This mode is when the outside air temperature is above the supply air set-point and below the return/exhaust air temperature (or enthalpy when desiccant technology and a total energy sequence is employed). In this mode, the wheel shall rotate at a minimum speed.
- Summer Mode: When the outside air temperature (or enthalpy) is above that indicated for the high side of the intermediate range, the wheel shall rotate at maximum speed.
- Anti-Frost: When the air temperature leaving the exhaust coil falls below 0ºC, the speed of the wheel shall be reduced to maintain that temperature at 0ºC.

# N. VAV/CV Terminals:

## N.1 VAV/CV Terminals General:

VAV control shall be pressure independent and shall be fully DDC on secondary controllers (exception: critical applications shall be controlled by primary controllers as indicated below). Damper fail position shall be as applicable to the space/component it is serving. Where there are no specific requirements for the fail position, it may be a cost effective floating (tri-state) actuator that fails in the last position. Commercial electronic actuators shall be provided unless indicated otherwise. Specialty applications are listed below. Elements of a typical VAV terminal sequence include:

- BAS shall modulate the air valve to maintain the air flow set point. Set point shall depend on the application. Examples are as follows:

    1. For temperature control when the primary air is below that required to maintain the room temperature set point, airflow set point shall be reset between minimum and maximum limits as the space temperature rises above the cooling set point. When zone requires heating, heating minimum limit shall be as dictated in the design.
    2. For Constant Volume Systems: airflow set point shall be dictated by the schedule. Occupied and unoccupied set points shall be as dictated in the design.

## N.2 Serving Zones with VAV Fume Hoods:

The control of the terminals shall be integral with the overall zone tracking logic as indicated under Zone Level. Actuators shall be fast acting (full stroke in <1s) electronic actuators. The fume hood controls shall be required to meet the aggressive control requirements mandated by the NIH / ASHRAE 110 Modified Fume Hood Testing Protocol. Therefore, consideration shall be given to having the fume hood exhaust terminal be provided by the control manufacturer. Supply and general exhaust terminals associated with that zone may be commercial grade as long as they are fitted with fast acting actuators and control contractor accepts responsibility for overall zone performance in writing. Dampers on fume hoods shall fail open. Where air flow is not measured and it is inferred from valve position as in a venturi valve application, the BAS shall monitor and alarm the condition where the pressure in the duct is inadequate to maintain the correlation.

## N.3 Reheat Control Valves:

Single duct boxes require a reheat coil valve analog output. This actuator shall be modulating. A cost effective floating actuator that fails in the last position may be used or a normally

open or closed valve as dictated by the application and the zone it serves. The A/E shall coordinate with the researcher to determine the best fail safe position. Examples include:

- Valves serving animal holding rooms shall fail in last position or closed.
- Fly rooms shall fail closed.
- Valves serving computer rooms shall fail in last position or closed.
- Valves serving standard occupied zones that have exterior walls shall fail in the last position or fail open. Those serving interior spaces shall fail in last position or closed.

## N.4 Floating Control Damper and Valve Actuators:

Floating control applications shall only be used in non-critical applications. Floating control damper and valve actuators may require period stroke recalibration which can cause upsets in pressure balance and short duration swings in temperature. Floating actuators also require recalibration on restoration of power which can delay returning to a steady state after a power outage. Examples of where floating actuators shall not be used include:

- Fume Hood, BSC, Canopy Hood, air control dampers.
- Vivarium Reheat Valves (where short duration temperature swings shall impact research).
- Containment and high containment spaces (nowhere are they allowed).

Examples of where floating actuators may be used include:

- Vivaria reheat valves where it can be shown that they never present a temperature variation that is outside acceptable ranges.
- Offices not part of adjacent critical laboratory space pressure control.
- Corridors not part of adjacent critical laboratory space pressure control.
- Miscellaneous terminal units serving support spaces like mechanical and electrical rooms.
- Laboratory airflow and reheat control where hoods are not part of the zone.

## N.5 Recalibration of Airflow Pressure Transducers:

Where pressure sensing in airflow applications requires periodic zeroing of the pressure transducer to maintain its accuracy, VAV terminal boxes serving laboratories shall include devices to allow re-zeroing of the pressure sensor without stroking the dampers. Spaces where these are not required include:

- Offices not part of or adjacent to a laboratory space pressure control.
- Corridors not part of adjacent laboratory space pressure control.

- Miscellaneous terminal units serving support spaces like mechanical and electrical rooms.

## O. Fume Hoods:

Fume hoods shall have flow monitors either provided by the control manufacturer (applicable to VAV hoods) or by the hood manufacturer (applicable to constant volume hoods). These monitors shall include indication of safe air flow, silenceable audible and visual alarms, which activate when face velocity is out of range (<90 or >110fpm), and an emergency ventilation switch or button. BAS shall at minimum monitor the alarm condition and the emergency ventilation position and enunciate an alarm on the operator workstation when either condition exists. The BAS shall also initiate any emergency ventilation sequences.

VAV fume hoods shall be controlled by a laboratory grade packaged control system that can meet the requirements of the NIH Fume Hood Testing Protocol. This shall require a full and stable response to a full sash movement within 3 seconds. VAV terminal used to control the airflow through the hood are addressed under the VAV Terminals section. The controller for the fume hood shall use sash sensors on the horizontal and or vertical sashes to determine the face area. Adjustments for hood leakage shall be possible. Based on the sash position and leakage, which shall include the airfoil area, the controller shall control the VAV terminal to the calculated air flow. Any independent hood monitoring and alarming device provided by the institute shall not be tied into the BAS.

## P. Ducted Biosafety Cabinets:

Ducted BSCs (Type B) shall be exhausted by house systems, which shall be controlled by the BAS. The exhaust flow from the cabinet shall be constant volume and can be controlled by a commercial grade terminal with a secondary controller unless the BSC is in a critical zone in which case it shall be controlled by the primary controller that is serving that zone. The cabinet shall be part of a flow tracking zone. Where ducted BSCs have an isolating damper on the exhaust to allow for decontamination, the closed position of this damper shall be monitored by the BAS. The system and BAS design shall maintain suite pressurization when the BSC is isolated for decontamination.

## Q. Miscellaneous Terminal Units:

Fan coil units, unit heaters, etc, shall be fully DDC controlled by application specific secondary controllers. Sensors requirements indicated for larger units do not apply. Status on fans does not apply. Where terminal units are provided supplementary to the house system, the two systems shall be coordinated to ensure they do not “fight” (heat and cool simultaneously).

# Section 7-6: Document Requirements



## 7-6-30 Design Document Requirements

Documentation Requirements: This section of the DRM defines the requirements for the documentation of the installed systems. The documentation covered herein shall be provided by the BAS vendor.

### A. Documentation Format:

### A.1 Hard Copy:

Provide paper copies of the indicated deliverables as directed by the Project Officer. Quantities shall be enumerated in the contract documents.

### A.2 Electronic Copy:

All submittal and record documents shall be provided electronically in any of the following formats:

- Microsoft Office components.
- Adobe Acrobat portable document format.
- HTML format.
- AutoCAD latest version used by the resource management group.

Different components may be in different formats however, one directory shall be provided in any of the first three formats with relative hyperlinks to all the documents.
One set of all submittals and electronic documents shall be provided in searchable Portable Document Format. This electronic document shall be organized with either bookmarks or hyperlinks to allow navigation from an electronic table of contents directly to individual control drawings, product data, schedules, wiring diagrams, etc.

Record control shop drawings shall be provided in AutoCAD format to allow editing and modification.

## B Submissions:

### B.1 Submittals:
BAS documentation indicated herein shall be submitted for approval as directed by the Project Officer.

### B.2 Record Documents and Drawings:
Record documentation as indicated herein shall be maintained and submitted to reflect final installed condition of BAS. The record documents shall be kept up to date throughout the construction period and submitted as final at final acceptance.

## C. Documentation Required:

### C.1 Control Schematics:
Control schematics shall be utilized to graphically indicate the systems, show the schematic configuration of the systems and location of control devices, define the point names and addresses, and define the set points for control elements. Control schematics are required both as part of the contract documents (generated by the A/E), shop drawing submittals, and record document submittals. The following shall be included in the controls schematics as a minimum:

- Point names (using convention dictated herein).
- Point addresses (not applicable to the contract documents).
- Point type.
- Normal position of output devices.
- Device ranges.
- Initial design intent set points modified as refined during construction for record submittals.
- Bill of materials listing all devices and manufacturer numbers (not applicable to the contract documents).
- Legend of device symbols.

### C.2 Product Data:
Submit manufacturer's technical product data for each control device, panel, controller, and accessory furnished, indicating dimensions, capacities, performance and electrical characteristics, and material finishes. Also, include installation and start-up instructions. Provide these as a part of the shop drawing and record submittal.

## C.3 Valve Schedules:

Either with the control schematic or separately in shop drawing submittal and record submittal; provide a valve schedule listing the following including actuator information:

- Size.
- Cv.
- Maximum flow.
- Pressure drop at maximum flow.
- Manufacturer.
- Model/product number.
- Close off rating.
- Normal positions.
- Valve Characteristic.
- Design controlled circuit pressure differential range (coordinated with the submittals).

## C.4 Control System Architecture:

Provide a system architecture one-line diagram indicating schematic location of all control units, workstations, LAN interface devices, gateways, etc. Indicate address and type for each control unit. Indicate physical media, protocol, baud rate, and type of each LAN. With the Control System Architecture Diagram at submittal stage, control vendor shall submit calculations estimating the speed of response for the reactions as dictated under the Infrastructure section of the DRM. These calculations shall be made to the point at which the architecture is completely under the control of the contractor which will not include the campus WAN. The assumption shall be made that the operator workstation is connected to the primary controller LAN.

## C.5 Control Sequence of Operations:

All projects shall include detailed sequence of operations. Sequences may be on the Control Schematics or in the specifications in the contract documents, and shall be included with the control schematics for the shop drawing and record submittal. Control sequences shall be highly detailed in the design phase and shall maintain this detail throughout the record submittal phase. As a minimum, the following shall be included:

- Sequences in all modes of operation On, Off, Occupied, Unoccupied, Warm-up, Cool down, summer, winter, Economizer, etc.
- Detailed steps during mode switches.
- Details of operation during and after a power outage. Prioritized restart sequences shall be specified by the A/E. Loss of status associated with power outages shall not be indicated as failures with a subsequent alarm or lock out.

- Specific direction on failure scenarios for loss of proof and all safety device trips.
- Set points, trip points, and ranges. Initially these shall be the A/E's intent, and eventually be the actual setting at time of record submittal.

## C.6 Points List:

A detailed point list shall be provided in tabular form. Indicate all physical and virtual points and organize by system/sub-system. Include names, descriptors, addresses (when known) and point types with applicable range as a minimum. These shall be provided electronically in either a database format or in a spreadsheet format.

## C.7 Zone Airflow Control Schedules:

Details of all control settings shall be provided in a schedule including minimum and maximum airflow, supply air temperature ranges, actuator types, ranges and fail positions, and terminal sizes and capacities. Where terminals are associated to form a pressure controlled zone, zone level minimum and maximum airflow shall also be indicated as well as the pairings of the boxes.

## C.8 Floor Plans:

Provide a set of floor plans with all controllers, sensors, operator workstations, interface devices, etc. located and identified.

## C.9 Detailed Wiring Diagrams:

Shop drawings and record submittals shall include detailed wiring diagrams. Indicate all required electrical wiring. Wiring diagrams shall include both ladder logic type diagram for motor starter, control, and safety circuits and detailed digital interface panel point termination diagrams with all wire numbers and terminal block numbers identified. Provide panel termination drawings on separate drawings. Ladder diagrams shall appear on system schematic. Clearly differentiate between portions of wiring that are existing or new and factory or field installed. These shall be submitted with shop drawing and record submittal

## C.10 Sample Graphics:

BAS vendor shall submit for approval sample graphics. The A/E and Project Officer, after consultation with operating organization shall approve or disapprove the graphics.

## C.11 Operation and Maintenance Manuals:

Provide Operation and Maintenance (O&M) Manuals in concert with training. O&M Manuals shall include the following:

- Maintenance instructions and spare parts list for each type of control device, control unit, and accessory.
- BAS User's Guides (Operating Manuals) for each controller type and for all workstation hardware and software and workstation peripherals.
- BAS Advanced Programming Manuals for each controller type and for all workstation software.
- Record Documents (product data, shop drawings, control logic documentation, hardware manuals, software manuals, installation guides or manuals, maintenance instructions and spare parts lists) shall be included in the O&M Manual.

Provide O&M Manuals in hard copy and text searchable (using standard Acrobat Search feature) .PDF electronic format.

# Section 7-7: Installation Requirements



## 7-7-00 Design Requirements

This section of the DRM defines requirements for the sensors, controllers, computers, and the components that make up the system and the means and methods in which they are installed.

### A. Point Naming Conventions:

All systems shall incorporate the point naming convention specific to the institution where the work is being done. Point names shall be verbose and segregation of parts of the point name shall be delimited with a period. Campus, Building, System, and Point will be typical elements of a point name; i.e.: East.Bldg01.AHU4.SA_Temp. Coordinate with the operating organization and get approval on the point naming convention if it is not already published.

## 7-7-10 Design Guidance

### A. System Controller Configuration:

### A.1 Overview:

The control system shall consist of primary controllers (which may include expander boards or remote point modules) and secondary controllers, which may include universal programmable controllers and terminal controllers. Each controller shall be located in the vicinity of the equipment or spaces monitored and controlled by the BAS, and communicate with the operator workstations and central servers as indicated under BAS Infrastructure. An overview of the use of the controller terminology is:

Primary Controller: This is a high powered flexible, programmable controller that communicates on a peer to peer LAN with other Primary Controller and operator workstations. It has a real time clock and high A/D precision and significant memory requirement. In some cases, it will supervise the communications between the secondary controllers (Universal programmable controllers and the terminal controllers) on a sub-LAN.

Secondary Controllers: The following secondary controllers are controllers connected to a secondary control LAN:

- Universal Programmable Controller: This is similar to the primary controller but it may reside on a polling sub-LAN. It is fully programmable but it is usually more restricted as to the point capacity and memory.
- Terminal Controller: This is an application specific controller that is cost effective for small, standard control sequences as is typical for a VAV box or fan coil unit.

The intent in identifying these categories of controllers is so that control functions can be required to be provided by a controller of that type. It is the A/E's responsibility to assign control functions to these controller categories according to the DRM and in consultation with ORF where specific direction is not provided. High-end controllers are more robust, reliable, and flexible, and can handle more trending, but cost more. Where the cost is not justified for a non-critical application, control functions can be provided by the cheaper controllers. Hand in hand with the controller, quality issue is the stand-alone functionality. This is another critical issue that the A/E shall dictate. It shall be made clear what control functions must be provided if a controller looses all communication. Various degrees of stand-alone functionality shall be specified for each system as the project budget dictates. Controllers shall be provided so that all points associated with and common to one system shall reside within a single controller. The boundaries of a stand-alone system shall be dictated in the contract documents. Standalone functionality requirements are made with reference to the processor. Where stand alone functions are required, one processor shall execute all the related I/O control logic via one operating system that uses a common programming and configuration tool. This shall not be violated without specific approval of the PO.

The functional intent of the DRM is to allow cost effective application of manufacturers standard products while maintaining the integrity and reliability of the control functions commensurate with their application.

## A.2 Primary Controllers:

A primary controller shall contain a microprocessor, memory, real time clock, communication interface, digital and analog I/O, controls, indicators, and power supply. The primary controller shall communicate with other primary controllers over a Primary Controller LAN which is high speed and peer to peer. They shall also communicate with the central servers and operator workstations which provides a mechanism for operator interaction, global parameter updates, and information requests and accepts information for alarm reporting, logging of events, generation of reports, and display. The primary controller shall function in an

independent (stand-alone per the definition below) mode performing the monitoring and control routines using applications software programs and operating parameters stored in the primary controller's memory.

The primary controller's capabilities shall include control of all physical parameters such as space temperature, space humidity, and supply water temperature without requiring data or operating parameters from the central server, workstation or other controller.

Primary controllers shall be capable of operating independently in stand alone fashion with no communication to other devices on the network. All points and functions that make up a functional system (shown on one control schematic) shall be included in one controller to qualify for this stand alone functionality. Where control sequences depend on global variables such as outside air temperature, panel shall have the capability of either using last value or a default value. The A/E shall specifically indicate point groupings for stand alone capability. Examples of required functional point groupings are:

- All points and functions required to control an air handler with all directly associated supply, return and exhaust fans. This excludes the terminals that may be associated with that air handler. Values that may be received across the network include:

    - Outside air temperature and humidity sensors.
    - Emergency power source indication except in critical applications.
    - Terminal based reset parameters.
    - Outside air temperature and humidity sensors.
    - Emergency power source indication.
    - Terminal based reset parameters.

- All points associated with the supply side of a hydronic system: pumps, flow meters, temperature and pressure sensors, proof indications, valves etc. This excludes the terminals on that hydronic system. Values that may be received across the network include:
- All points and functions required to control one terminal system including dampers, valves, flow meters, temperature and humidity sensors, etc. This does not include the scheduling period or any outside conditions that may be necessary for control.

Exception: Where a variable speed drive is part of the controlled function, when approved, the drive may include a separate field panel controller. However, all aspects of failure and loss of communication shall be considered, enumerated in the sequence, and thoroughly tested.

The primary controller shall include sufficient memory to contain the operating system, applications software, and database, control sequences for all required operation, and ALL REQUIRED TRENDING when trending is buffered in the controller. Where control system operation is hindered by the shortage of memory, contractor shall at no cost to NIH either upgrade the memory or provide multiple controllers.

Primary controllers shall communicate with other primary controllers and operator workstations via a peer to peer LAN with segment recovery at a baud rate not less than 78Kbaud. Primary controllers shall provide an input A/D converter precision of at least 12 bit.

Resumption of power after an outage shall cause the primary controller to automatically restart and establish communications with the central server. If the primary controller is unable to establish communications, it shall still perform all required functions while saving certain data for later uplink to the central server. Primary controller shutdown based on a self-diagnosed failure in the power supply, hardware, or software shall set each piece of controlled equipment to a predetermined failure mode.

Controllers shall be powered from the most reliable source that powers any of the systems it serves. In the situation where the primary controller shall be required to continuously collect data to be transmitted to the workstation, or where it monitors critical recovery information such as the presence of emergency power, it may be necessary to provide an uninterruptible power system for the entire primary controller as well as any sensor and controller power required. Where panels are provided with a different power source as the equipment (such as when the panel is on a UPS), the panel shall be provided with a means of monitoring the power source to the controlled equipment. This can be a dedicated monitor as an input or an input coming from transfer switch contacts.

BO points on primary controllers controlling motors or critical valves or dampers shall be provided with HOA functionality. Where the controlled device is not provided with a separate status indicator, an input shall be provided to monitor the hand position. Where the hand condition is determined through an independent status monitor such as a fan or pump with a current switch or a valve or damper with an end switch, this input is not required.

Remote Point Modules: Remote point modules serve as I/O devices for primary controllers and functionally are an extension of the primary controller. Remote point modules transmit their data to the primary controller over a data transmission circuit. This communications circuit shall not be shared with secondary controllers. Failure of a remote point module shall set each piece of controlled equipment to a predetermined failure mode. Remote point modules shall have an uninterruptible power system where their associated primary controllers also require an uninterruptible power system.

Built Up Primary Controllers: Where manufacturer's product line does not include a primary controller, they may meet the intent of the primary controller requirement by packaging a network communications controller module with a Universal Programmable Controller. This "controller secondary LAN" shall be dedicated to the functions directly required by the primary controller and the UCP shall not compete with any other traffic on the secondary LAN than what is required for the controller operations. One programming language shall be used for all sequencing.

## A.3 Secondary Controllers:

Universal Programmable Controllers: Universal programmable controllers (UPC's) shall be field programmable stand-alone controllers with flexible I/O configuration. The UPC will contain a seven-day calendar and a real-time clock so that its scheduled operations are maintained independent of communication with the primary controller or network communication control module. Because of the potential cost benefits of universal programmable controllers, the A/E shall consider their use less critical applications than would require a Primary Controller. UPC's may obtain secondary control variables (such as set point resets, outside air temperature, emergency power status) from a primary controller, network communications controller module, or other UPC. In the event of loss of communication, the UCP shall control to either the last know network variable or to a set default condition defined at configuration. UPC's shall have A/D conversion of at least 10 bit.

BO points controlling motors or critical valves or dampers shall be provided with HOA functionality. Where BO function is not provided with a separate status indicator, an input shall be provided to monitor the hand position. Where the hand condition is determined through an independent status monitor such as a fan or pump with a current switch or a valve or damper with an end switch, this input is not required.

Terminal Controllers: Terminal controllers are application specific controllers with a fixed complement of I/O functions and fixed (or minimally configurable) applications programs. Their program will accommodate specific operating requirements of utility system equipment by the selection of a small number of set points and operating parameters.

Controller Input/Output (I/O): Electronic circuits shall enable the BAS controllers to interface with the system I/O devices. The BAS controller shall directly support analog, binary, and pulse accumulator electrical input signals as well as analog and binary electric and pneumatic output control signals. Analog data to and from building systems shall be conditioned to ensure signal level and type compatibility.

### A.4 Wire lines:

Use physical media for controller to controller or controller to I/O device communications. Wiring shall be twisted pairs that consist of two solid copper insulated conductors twisted and shielded together to minimize interference by unwanted signals.

Select twisted shielded pairs to carry information with highest speed possible depending on the in-place characteristics of the existing field panel or field equipment communications. Select twisted shield pairs to obtain the highest field equipment communications.

Control wiring shall be run to avoid EMI interference from other equipment. Control wiring shall not be run through a VFD cabinet. Control wiring shall be run in its own raceway.

### A.5 Power to Controllers:

Power to controllers shall be at a minimum the most reliable source that powers equipment controlled by that controller. For instance, if the controller serves a fan that is on emergency power, the controller shall at least be fed from an emergency circuit. On critical applications, controllers shall be powered from uninterruptible power supplies to maintain continuous operation throughout power outages and transfers. Where the controller power is a different source than that which feeds the equipment, then some form of monitoring shall be provided to inform the controller of the state of the power to the served equipment. 3-phase monitors may for instance be used as inputs to the controller. Positions of transfer switches may also be monitored.

In critical applications, where power transfers from emergency power back to normal shall result in open transitions that may cause controls or equipment to stop or fail, consider requiring the BAS to monitor the a point that indicates that a transfer is eminent so that the controller can execute a controlled stop and restart.

## B. Sensors:

### B.1 Temperature Sensors:

Sensor Range: When matched with A/D converter of the controller, sensor range shall provide a resolution of no worse than 0.16°C (0.29°F) (unless noted otherwise). Where thermistors are used, the stability shall be better than 0.15°C (0.27°F) over 5 years.

Matched Sensors: Matched sensors are those that are tested by the manufacturer and certified to indicate within 0.2°C (0.5°F). The following applications shall require matched sensors:

- Building Loop Connections: provide matched loop and building supply sensors where control sequence requires controlling to a temperature rise.
- Hydronic Temperature Difference Calculations: Provide matched supply and return temperature sensors where the pair is used for calculating temperature difference for use in load calculations or sequencing.

Room Temperature Sensors: These shall be an element contained within a ventilated cover, suitable for wall mounting. Provide insulated base. Following sensing elements are acceptable:

- Sensing element - Platinum RTD, Thermistor, or integrated circuit, +/-0.5°C (+/-1°F) accuracy at calibration point.
- Provide set point adjustment where approved by the Project Officer. The set point adjustment shall be a warmer/cooler indication that shall be scalable via the DDC system.
- Provide an occupancy override button on the room sensor enclosure where occupied/unoccupied sequences are used. This shall be a momentary contact closure.

When one temperature sensor is used to control multiple thermal zones intended for occupancy by different people in the various zones, sensors shall not have space temperature adjustment.

Single Point Duct Temperature Sensors: These shall consist of sensing element, junction box for wiring connections and gasket to prevent air leakage or vibration noise. Temperature range as required for resolution indicated in above. Sensor probe shall be 316 stainless steel.

- Sensing element - Platinum RTD, Thermistor, or integrated circuit, +/-0.12°C (+/-0.22°F) accuracy at calibration point.

Low Limit Duct Temperature Sensors: Low limit preheat temperature sensor consist of low limit element, junction box for wiring connections and gasket to prevent leakage or vibration noise. Sensing element shall be one linear meter for each one square meter of coil face area. Sensor shall read lowest temperature on any 0.3 meter section of sensing element. Sensing element shall be evenly placed in serpentine configuration on downstream side of preheat coil between coil and next heat transfer component.

Averaging Duct Temperature Sensors: These shall consist of an averaging element, junction box for wiring connections and gasket to prevent air leakage. Provide sensor lengths and quantities to result in one lineal meter of sensing element for each three square meters of coil/duct face area. Temperature range as required for resolution indicated above.

- Sensing element - Platinum RTD, +/-0.12°C (+/-0.22°F) accuracy at calibration point.

Liquid Immersion Pipe Temperature Sensors: These shall include brass or stainless steel thermowell, sensor and connection head for wiring connections:

- Sensing element (chilled water)- Platinum RTD +/-0.2°C (+/-0.36°F) accuracy at calibration point. Temperature range shall be as required for resolution of +/-0.15°C (+/-0.27°F).
- Sensing element (other systems) - Platinum RTD, Thermistor, or integrated circuit, +/-0.23°C (+/-0.41°F) accuracy at calibration point. Temperature range shall be as required for resolution of 0.17°C (0.31°F)

Pipe Surface Temperature Sensors: These shall include metal junction box and clamps and shall be suitable for sensing pipe surface temperature and installation under insulation. Provide thermally conductive paste at pipe contact point. Temperature range shall be as require for resolution indicated above. These shall not be used without specific permission of the Project Officer.

- Sensing element - Platinum RTD, Thermistor, or integrated circuit, +/-0.23°C (+/-0.41°F) accuracy at calibration point.

Outside Air Temperature Sensors: These shall consist of a sensor, sun shield, utility box, and water tight gasket to prevent water seepage. Temperature range shall be as require for resolution indicated above.

- Sensing element - Platinum RTD, Thermistor, or integrated circuit, +/-0.23°C (+/-0.41°F) accuracy at calibration point.

## B.2 Temperature Transmitters:

Where required by controller, sensors as specified above may be matched with transmitters outputting 4-20 mA linearly across the specified temperature range. Transmitters shall have zero and span adjustments, an accuracy of 0.06°C (0.11°F) when applied to the sensor range.

## B.3 Humidity Sensors:

Unit shall produce linear continuous output of 4-20 mA for percent relative humidity (% rh). Sensors shall have the following minimum performance and application criteria:

- Input Range: 0 to 100% rh.
- Accuracy (% rh): +/- 2% (when used for enthalpy calculation, dew point calculation or humidifier control) or +/- 3% (monitoring only) between 20-90% rh at 25°C (77°F), including hysteresis, linearity, and repeatability.

- Sensor Operating Range: as required by application.
- Long Term Stability: Less than 1% drifts per year.

## B.4 Pressure Sensors:

Pressure sensors shall be provided with a range commensurate with the application. Accuracy shall be specified to be commensurate with the requirement.

Air Static and Velocity Transmitters: Applications: Static pressure or differential static pressure and VP. Provide the smallest range feasible for the application. Provide zero and span adjustments:

- Accuracy: plus or minus 1% of full scale for static and 0.25% for air velocity
- Auto-zero modules shall be used on airflow transmitters to periodically re-zero the transmitter.

Liquid Differential Pressure Transmitters: Pressure transmitters shall gauge pressure in the form of a linear 4 to 20 mA signal. All components shall be hermetically sealed in a Type 316 stainless steel case. Provide wall mounted 5 valve cabinet for mounting of transmitter. Pressure transmitters shall meet the following performance criteria:

- 0.5% accuracy over the entire span.
- Repeatability: plus or minus 0.1% at maximum span.
- Stability: plus or minus 0.25% of upper range for a period of 6 months.

## C. Flow Sensors:

Flow sensors shall be carefully placed to ensure flow profiles that are required for accurate flow sensing. Designs shall specifically indicate the location of the sensors and indicate the length of unobstructed duct or pipe. For flow meters, temperature and pressure sensors, the A/E shall carefully consider all manufacturers requirements for piping free run (required upstream and downstream diameters), distance from obstructions, devices or valves, and piping geometry requirements (i.e., elbows in/out of plane). Strict attention shall also be paid to minimum and maximum velocity requirements. Piping size reductions in metering section may be required to maintain reasonable minimum velocities for majority of annual conditions. See HVAC Chapter VIII.B.5 “Steam Systems.”

## C.1 Water and Steam Less than 2:1 Turndown:

Use an inline venturi flow meter with a differential pressure transmitter as specified above. Differential pressure may be linearized in the transmitter or by the BAS.

- Accuracy in a properly located meter shall be better than 5%.

## C.2 Water and Steam Greater than 2:1 Turndown:

Provide either a Turbine flow meter, vortex shedding meter, magnetic meter or, when measuring water, an ultrasonic flow meter.

Turbine Flow Meter: Turbine flow meters may be used for measuring flow of chilled water and steam with a high turn down ratio unless prohibited by pipe size. The turbine flow meters shall be installed so that they may be immersed and removed for maintenance and calibration without disrupting flow. "Hot tap" methods shall be used to install turbine flow meters in existing line under pressure.

- Accuracy in a properly located meter shall be better than 5%.

Ultrasonic Flow Meter: Ultrasonic flow meters may be used for measuring flow of water systems with a high turn down ratio.

- Accuracy in a properly located meter shall be better than 5%.

Vortex Shedding Flow Meter: Vortex shedding flow meters may be used for measuring flow of steam systems with a high turn down ratio.

- Accuracy in a properly located meter shall be better than 5%.

Magnetic Flow Meter: Magnetic flow meters may be used for measuring flow of water or steam systems with a high turn down ratio.

- Accuracy in a properly located meter shall be better than 5%.

## C.3 Air Flow > 5 m/s:

Use a pitot tube averaging grid of a material compatible with the environment.

## C.4 Air Flow < 5 m/s:

Use hot wire anemometer grid or vortex shedding grid stations rated for the environment they are applied in. Both types shall have sensing elements distributed throughout the cross-section of the duct. If used in outside air ducts, ensure the sensor element is rated for the conditions of its duty.

## D. Current Switches (CS):

### D.1 For Constant Speed Motors:

Current switches shall be provided for status indication of constant speed motors. Switch shall indicate loss of status when current falls below an adjustable trip point. CS shall include LED indication of status.

### D.2 Variable Speed Motors:

Current switches shall be provided for status indication of variable speed motors. In applications where minimum operating amp draw is less than no load motor amp draw at 60 Hz, Switch shall be Self Calibrating based on VA memory associated with frequency. This shall form a curve to determine the trip point based on speed such that it shall detect a belt break with subsequent increase of control output to 60 Hz. CS shall include LED indication of status. In critical application, proof or loss of proof shall consistently indicate within 10 seconds of event.

## E. Control Valves:

### E.1 General:

Valves shall be applicable for the rated pressure and temperature service. Close off pressures, determined in concert with the actuators and valves, and shall be specified to close off against extreme anticipated conditions.

Modulating valves shall be carefully selected to control in a smooth and stable fashion across the range of anticipated conditions. General requirements are indicated below. Flow characteristic analyses shall be submitted when the selection criteria indicated below is not met to demonstrate reasonable correlation between stroke and flow.

All valves over 25 mm (1 in.) shall have a position indicator. The BAS output to modulating valves shall be analog with the following exceptions:

- Terminal reheat valves may be floating or PWM when not serving critical spaces.
- Fan coil and unit heater and similar terminal device valves may be floating or PWM.

### E.2 Steam:

Steam control valves shall be cage guided globe or plug valves with a linear characteristic. Modulating valves shall be sized for in excess of 75% of the rated steam supply temperature. Fail positions shall be as follows:

- Primary Heating: As dictated for occupancy or application but normally open as a default.
- Clean Steam: normally closed.
- Humidifiers: normally closed.

## E.3 Water:

Modulating water valves may be globe, ball, or butterfly valves with an equal percentage characteristic (with the exception of the building chilled water valve controlling flow from the loop which shall be linear). Modulating water valve shall be sized for greater than 50% of the controlled circuit pressure drop. Fail positions shall be as follows:

- Primary Heating: As dictated for occupancy or application but Normally Open as a default.
- Primary Cooling: Normally open serving a 100% outdoor air units and or cooling only applications. Otherwise, they shall be normally closed.
- Building Chilled Water Valve: normally open.
- Terminal Reheat: Last position or as dictated by the zone served.

Water Pressure Independent: Modulating water valves may be pressure independent such that they maintain a given flow at a given stroke within required pressure range.

## F. Control Dampers:

Dampers shall be applicable for the rated pressure and velocity service. Damper structural rating shall exceed extreme anticipated conditions like fan dead head. Modulating dampers shall be carefully selected to control in a smooth and stable fashion across the range of anticipated conditions. Except where associated with a mixed air section and used for promoting mixing, and except where sizes dictate single blade, dampers shall be opposed blade. Outside air control dampers shall be low leakage dampers with damper seals.

Output to modulating control dampers shall be analog with the following exceptions:

- Standard VAV terminal dampers may be floating or PWM when not serving critical applications.

## G. Actuators:

Size actuators and linkages to operate their appropriate dampers or valves with sufficient reserve torque or force to provide smooth modulating action or 2-position action and adequate close off rating as required. Actuators shall be electronic unless there is a compelling

case for pneumatic. For instance high torque damper actuators used for containment and high containment applications shall be pneumatic.

- Standard Electronic Actuators: shall be designed for a minimum of 60,000 full cycles at full torque and be UL 873 listed. Provide stroke indicator. Actuators shall have positive positioning circuit and selectable inputs. Full stroke shall be within 90 seconds. Where fail positions are required, provide spring return on the valve with adequate close off force.
- Fast Acting Electronic Actuators: Provide fast acting electronic actuators for VAV terminals on fume hood and associated tracking zone dampers. Also, provide fast acting actuators on all critical applications such as containment and high containment laboratories. These actuators shall move full stroke in less than one second.
- Pneumatic Actuators: Provide heavy duty actuators with stroke indication and spring return. When so indicated and where more than 2 actuators are to be operated in sequence to each other, provide position feedback positive positioners with adjustable start point and operating range. Also, provide positive positioners on all modulating pneumatic valves larger than 50mm and as shown on drawings.

## H. Compressed Air Systems:

Where compressed air systems are used, they shall meet the following requirements. Note that compressed air applications for controls shall be limited to special cases where very large torque is required.

The instrumentation air compressor shall be oil free. Use duplex air compressors sized for less than one third duty cycle. Size storage to prohibit more than six starts an hour on any compressor.

Where the building system is a back up to the campus system, connect the new systems as a backup to the plant air and to provide control air when the plant air pressure drops below the needed pressure. The instrumentation air supply shall have an air drier. A refrigerated dryer will suffice. However, when continuous air consumption is required on a device or through a pipe that is exposed to outside conditions, a desiccant drier shall be provided. Filtration shall be provided before and after the air dryer. Air filters shall be installed with bypass and isolation valves to permit filter replacement without instrument air supply disruption.

Air drying and filtration at buildings shall be provided when only plant air is being used. Compressed air shall be distributed at high pressure with zoned pressure reducing stations.

Where the controls are serving critical facilities, an alternate source shall be provided. A campus air source and a local installation shall meet this requirement. A control air skid backed up by a laboratory air compressor shall also meet this requirement.

Control air shall be pressurized to a high pressure for supply and storage. This pressure shall be adequate to meet the requirements of the system. Pressure reducing stations shall then be provided to reduce and trim the pressure to a consistent pressure. PRV stations shall include redundant PRV's and a manual bypass. Each compressed air supply shall include a filter dryer which again shall be redundant to allow uninterrupted operation.

## I. Control Tubing:

All copper tubing in mechanical equipment rooms shall be hard- drawn Type L copper.

All tubing installed above non-plenum return lift-out ceilings shall be Type FR self-extinguishing polyethylene.
All tubing installed in plenum return ceilings shall be soft copper Type L.

All control tubing installed in vertical chases shall be hard copper. Drip legs on vertical risers and shutoff valves shall be located in an accessible location where main leaves the riser.

All control tubing installed in non-accessible walls or ceilings shall be soft copper.

All control tubing installed outside shall be jacketed hard copper for single lines and sheathed polyethylene for multiple lines. All lines outdoors shall be heat traced.

All tubing in control panels shall be Type FR polyethylene.

All control air hangers shall be clamp type and shall not be attached to other trades.

All connections shall be sweated fittings.

All air lines shall be installed in straight lines in harmony with building construction. No control lines shall be run exposed in occupied spaces.

## J. Control Wiring:

All control wiring in mechanical equipment rooms or other spaces in which it is readily accessible shall be installed in electrical metal tubing (EMT) with compression fittings.

All control wiring run in interstitial spaces shall either be run in electrical metal tubing (EMT) with compression fittings or a cable tray or raceway.

All control wiring installed outdoors or any area subject to moisture shall be installed in rigid conduit.

All control wiring installed in vertical chases shall be installed in EMT with compression fittings.

All control wiring above non-accessible ceilings shall be installed in EMT with compression fittings.

All control wiring installed above accessible ceiling spaces which are not laboratories or animal holding areas shall be plenum type, not installed in conduit, but neatly run with generous use of rings or ties.

Similar control functions shall have a similar wire color.

Wire shall be un-spliced from the controller to the sensor.

All terminations shall be on terminal strips.

Color codes all raceways and junction boxes with color directed by Design Engineering Group.

Control wiring shall not be routed in the same raceway as power wiring.

## K. Wall Penetrations:

Wall penetrations for the BAS shall be prepared and sleeved. Wall penetrations through fire rated walls shall be avoided. Where necessary, penetrations shall be in accordance with NFPA and NIH regulations. All fire-rated features of the contract design must be approved by DFM.

Where controls penetrate biocontainment barriers, penetration shall be in accordance with the BSL3 and ABSL3 sealing and caulking requirements.

## L. Transient Protection:

The BAS electrical power supply, data transmission system, and input/output functions shall be protected against transients.

# M. Software and Software Setup Requirements:

## M.1 Controllers:

Controllers shall be provided with a real time operating system resident in ROM. This software shall execute independently from any other devices in the system. It shall support all specified functions. It shall provide a command prioritization scheme to allow functional override of control functions. At a minimum, the following shall be provided:

- Real time operating system software.
- Real time clock/calendar and network time synchronization (except Terminal Controllers).
- PCU diagnostic software.
- LAN communication software.
- Direct digital control software.
- Alarm processing and buffering software.
- Energy management software.
- Data trending, reporting, and buffering software.
- I/O (physical and virtual) database. Inputs and outputs shall have the capability to be overridden for emergency modes and testing. If the design documentation does not specifically indicate which points this is required on, Control vendor shall request in writing which points this capability is required on. If they do not request this in writing, they shall reprogram or reconfigure the systems as required during testing.
- Remote communication software.

## M.2 Password Protection:

BAS software shall provide for restricted access to the system parameters based on user rights assigned by the administrator. Control vendor shall coordinate with maintenance staff for assignment. Each new facility shall include at least 10 new user setups with rights customized as dictated by maintenance staff. Where the project incorporates a balancing contractor and or commissioning agent, control vendor shall provide them with appropriate passwords.

Password protection shall be granular with the capability to provide rights by group of point, by type of task, by level of security, etc.

On containment and high containment applications, access restrictions capability shall include the ability to require supervisory confirmation of additions and changes to the BAS and have all steps tracked in an auditing log.

## M.3 Containment Validations:

In containment applications, the BAS software shall conform to Title 21 CFR 11, Electronic Signatures, to provide a secure audit trail of performance and system additions and changes.

## M.4 Alarming and Message Routing:

BAS shall provide for alarming, alarm management, and alarm routing. Each controller shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic, and prevent alarms from being lost. At no time shall a controller's ability to report alarms be affected by either operator activity at an Operator Workstation or local handheld device, or by communications with other panels on the network. BAS shall provide for a prioritization scheme that allows associated routing and alarm management. Upon receipt of an alarm at a graphic workstation, the alarm condition shall be enunciated regardless of any other part of the graphic software being open. Alarm management features shall include:

- The ability to acknowledge and silence an alarm based on appropriate user password level.
- Automatic notification on return to normal.
- Storing the alarms in a database that shall allow various queries by system, point, etc. and by status and priority level.
- BAS shall have capability to email or phone alarms to central call-in desk or other designated people.

Each new system or extension of the BAS shall include the configuration of alarm routing as required by maintenance staff.

## M.5 Trending:

To support commissioning and building data mining, BAS shall be capable of trending and archiving all points on primary and universal programmable controllers at a minimum of 15 minute intervals. BAS shall also have the capability of trending at least 3 points on each terminal controller at an interval of 30 minutes. Controller memory capability and control bandwidth shall be designed to account for this trending. Control trends shall be established by the control vendor during start up and prior to functional performance testing of the systems. When native trend store is not in a commonly acceptable format, reports shall be scheduled to output the data to a common format. Comma separated text; Microsoft formats such as Excel and Access, portable database format are considered common formats. Alternatively, the OLE DB or ODBC driver to access the native store can be provided royalty free.

## M.6 Trend Graphs:

Software shall provide for displaying line graphs or graphic plots of the trended values. Software shall support multiple scales. Control vendor shall configure these graphs in a logical manner for each system.

## M.7 Dynamic Graphs:

Software shall provide for real time plotting/graphing of multiple values. Control vendor shall configure these graphs in a logical manner for each system.

## M.8 Graphic Screens:

Floor Plan Screens: Provide graphic floor plan screens for each floor and or section of the building. Indicate the location of all equipment that is not located on the equipment room screens. Indicate the location of temperature sensors associated with each temperature controlled zone (i.e., VAV terminals, fan-coils, single-zone AHU's etc.) on the floor plan screens. Display the space temperature point adjacent to each temperature sensor symbol. Indicate room numbers as provided by the NIH. Provide a graphic link from each zone and/or equipment symbol shown on the graphic floor plan screens to each corresponding equipment schematic graphic screen.

Provide graphic floor plan screens for each mechanical equipment room and a plan screen of the roof. Indicate the location of each item of mechanical equipment. Provide a drawing link from each equipment symbol shown on the graphic plan view screen to each corresponding mechanical system schematic graphic screen.

If multiple floor plans are necessary to show all areas, provide a graphic building key plan. Use elevation views and/or plan views as necessary to graphically indicate the location of all of the larger scale floor plans. Link graphic building key plan to larger scale partial floor plans. Provide links from each larger scale graphic floor plan screen to the building key plan and to each of the other graphic floor plan screens.

Provide a graphic site plan with links to and from each building graphic.

System Schematic Screens: Provide graphic system schematic screen for each HVAC subsystem controlled with each I/O point in the project appearing on at least one graphic screen. System graphics shall include flow diagrams with status, setpoints, current analog input and output values, operator commands, etc. as applicable. General layout of the system shall be schematically correct. Input/output devices shall be shown in their schematically correct locations. Include appropriate engineering units for each displayed point value.

Verbose names (English language descriptors) shall be included for each point on all graphics; this may be accomplished by the use of a pop-up window accessed by selecting the displayed point with the mouse. Indicate all adjustable set points on the applicable system schematic graphic screen or, if space does not allow, on a supplemental linked set point screen. All outputs shall be represented in terms of percent open:

- Provide graphic screens for each air handling system. Indicate all control point values, (See Application Requirements for required points) and mode of operation as applicable (i.e., occupied, unoccupied, warm-up, cool-down). Link screens for air handlers to the heating system and cooling system graphics Link screens for supply and exhaust systems if they are not combined onto one screen.
- Provide a graphic screen for each hydronic system.
- Provide a graphic screen for each terminal unit. In addition to points associated with the unit, indicate mode of operation as applicable (i.e., normal occupied, unoccupied, warm-up, maxi-mum heating, and maximum cooling). Provide links between the applicable floor plan screen and this screen. Also, provide links to the graphics representing the parent systems.
- Link screens for heating and cooling system graphics to utility history reports showing current and monthly electric uses, demands, peak values, etc.

## M.9 Reporting:

General: BAS shall support automatic report generation and storing report output in some form of database. Software shall have capability to sort and tabulate based on point, time, point value, alarm status, etc.

Building Utility Reporting: For each new facility, control vendor shall configure utility reports as indicated under Building Level requirements of the DRM.

Vivarium Reporting: Refer to Vivarium Monitoring Workstation

## N. Operator Workstations:

Graphic operator workstations shall be provided as indicated under BAS Infrastructure section of the DRM. This section covers the hardware requirements of the operator workstation. The software requirements are covered above in Software and Software Setup Requirements.

Below are general requirements for operator workstation computers. The A/E shall refine these requirements to keep current and be commensurate with the need. All computers provided as stationary operator workstations shall be include the following:

- Processor speed, disk storage capacity, and memory shall be at least what are available at the time of installation as a mid range offering of major computer retailers. The A/E shall convert the DRM to a specification.
- Read/write compact disk with speeds commensurate with current offerings.
- Operating system shall be Microsoft Windows based no earlier than 2000.
- 1024 x 768 resolution (at the minimum) 432 mm (17 in.)[at the minimum] monitor.
- 280 mm x 432 mm (11 in. x 17 in.) color printer.
- 216 mm" x 280 mm (8-1/2 in. x 11 in.)continuous feed alarm printer.
- 100 mbs Ethernet card for connection to the campus WAN.
- Uninterruptible Power Supply for at least 30 min of operation.

## O. Commissioning:

BAS shall be commissioned in accordance with the NIH Commissioning Standard. All testing, demonstration, documentation, and training shall be required as if stated therein.

# Plumbing

8



# Section 8-1: Plumbing Design Considerations



## 8-1-00 Design Requirements

The requirements of this chapter apply to systems within the plumbing and process piping engineering disciplines, including but not limited to various water, waste and drainage systems, process and fuel gasses, medical gasses, vacuum services, special process fluids, as well as associated fixtures, equipment, controls and appurtenances. The program goals and objectives herein are intended to provide uniformity of design based on the requirements of the DRM, combine the best overall economy with suitability of design, and promote compatibility with other building systems and operational procedures. The term “Plumbing” as utilized in this chapter is used loosely to broadly characterize all plumbing and process piping systems within the scope of this chapter.

### A. General Planning Requirements:

The plumbing systems shall be coordinated with the laboratory-planning module. Adequate fluid temperature, pressure, and volume shall be delivered to required laboratory functions through conservatively sized pipe mains and careful review of programming and equipment requirements, in addition to the requirements of the DRM. Future capacity allowances need to be considered in building designs including utility services, main risers and major branch lines, as well as equipment room space planning and interdisciplinary coordination of projected future requirements.

Building services (such as centralized bottled gases and compressed air required for research), shall be considered in the design to facilitate modular systems and services for the facility. Manifolding gases and decentralizing some services can be evaluated as described herein.

Provision shall be made for the addition of future loads on a project-by-project basis, and in some cases may need to exceed the requirements of the DRM. Early planning and coordination with the entire design team is critical and close coordination between mechanical, electrical, and structural disciplines is required to minimize interference of

piping/ventilating systems and electrical systems, with structural framing. See Section 1 Integrated Pest Management for pest control requirements.

Plumbing requirements are often dictated by user and program requirements during the design phase. These are subject to change because of improving equipment technology and the need to remain state-of-the-art when the construction process is completed. The A/E shall clearly understand the wide range of utility requirements and design flexible distribution systems to support future connections.

## B. Animal Research Facilities, Special Considerations:

Types of plumbing systems in the animal facility may include wash systems, waste drainage systems, animal drinking water systems, and vivarium gas systems. Plumbing systems specifically installed for animal support require close review with an animal care specialist to determine the exact requirements.

Requirements for animal facility plumbing system design shall carefully minimize the potential for accumulating dirt and pest harborage; promote controlled and limited access to the animal care areas; and ensure that all pipes, mounting brackets, supports, etc. are caulked and sealed during installation. Systems shall be designed in as much as possible to preclude disruption or disturbances to animals through normal operation and maintenance. Escutcheons shall be avoided at piping penetrations, and the use of access doors opening into walls and ceilings should also be avoided. Exposed piping inside animal research facilities shall be minimized, and where required shall standoff from walls at least 25 mm (1 in.) to permit cleaning and minimize concealed fouling spaces.

Special care is needed in the design of facilities for Specific Pathogen Free (SPF) animals to minimize potential for cross contamination and maintain the sanitary environment. Design issues such as quality and source of drinking water, clean and sanitary surfaces, sealing and cleanliness of penetrations, isolation from potential contaminant sources and adjacent spaces etc. all must be considered.

## B.1 Special Plumbing Considerations for Aquatics:

Slight variations in water salinity, temperature, or pH can kill the animals., therefore systems shall be designed to ensure precise and adequate control, failsafe protection, and monitoring. Controls shall be properly calibrated. Piping shall be of an inert material. Plastic resins shall be free of lead and shall not leach chemicals. Metal piping, especially copper and zinc piping, shall be avoided since it leaches chemicals that are toxic to most aquatic species. Floor drains shall be designed to minimize the retention of organic matter (no recesses, inaccessible lips, etc.) and be easily accessible for cleaning and pest management inspec-

tion. If a saline environment is required, the equipment shall include a supply-mixing tank upstream from the holding tanks. In a saline environment, all materials shall be corrosion resistant, including receiving drains and fixtures. Stainless steel is not utilized for drains and components in saline environments. Treatment and distribution systems for aquatics shall be designed by an engineer experienced in such specialty, and shall include comprehensive consultations with the use group.

## C. Common Technical Requirements:

### C.1 Capacity:

Overall, the design of the piping distribution shall be based on a modular layout. Systems shall be designed to ensure reliability, maximize operational flexibility and capacity for renovation, allow service to occur without interfering with research, and to minimize potential for disruption due to single point failures and routine maintenance. A primary goal for distribution systems is to minimize floor penetrations in laboratory areas. Primary equipment, service mains and risers shall be sized to provide 20% overage beyond required design loads to allow for increased future demands and density compression, separate from any known expansion. The A/E shall utilize efficient capacity split for sizing primary equipment to provide required redundancy and overage while maintaining efficient operation for the normal operating load profile.

Whenever connections are made into existing systems to serve new equipment, additions, or renovated areas, the A/E shall ensure the existing system will not be adversely affected or in any case fall below the standards of code or NIH DRM requirements as a result of the new work. This may require the A/E to study existing infrastructure and systems capacity far beyond the actual planned point of connection to ensure adequacy.

### C.2 Distribution:

Pressurized piping distribution systems shall consist of main system vertical risers that are located in permanent mechanical shafts or at building structural columns, or in the case of utility corridor building concepts, main risers may be located at each end of the utility corridor. Vertical risers shall not be located within laboratory program area, behind individual fixtures, or in any other manner that does would not promote complete and independent horizontal distribution and isolation of services to each floor from main system risers located in an area outside the primary program space.

Horizontal distribution mains shall be located in permanent chases, ceilings, or interstitial spaces, with individual room runouts to accommodate the architectural layout of the

building. A utility corridor concept or interstitial space concept is generally used for biomedical laboratory and animal research facilities. The design approach shall result in a repetitive and standardized grid arrangement of the risers, mains, branches, and runouts. Piping and valving arrangements shall allow for shutdown of individual laboratories, as well as independent isolation of each floor, building wing, and zone without affecting other areas.

Redundant risers, remotely located at each end of the building wing or near each end of the corridor shall be provided for water service, carbon dioxide, and any additional pressurized service deemed necessary to preclude loss of research and permit continued facility operations during times of renovation or repair. Ideally, these risers should be located such that one riser is in the building wing served, and a secondary redundant active riser is located outside the building wing or in an area common to multiple building wings, thereby permitting complete renovation of any building wing without affecting adjacent areas. These risers shall be interconnected at least at the top and bottom, and at the A/E option may be interconnected on each floor. Valving shall be provided above, below, and on each floor take-off from the riser to permit each riser to be utilized in a bi-directional feed mode as may be necessary to allow continued operation with either riser or any segment of a riser isolated. The need for redundant risers for lab vacuum, compressed air, RO and other process services shall be determined on a case by case basis and is not automatically required. Secondary services (such as for hot water circulation) need not be redundant. In general, systems shall be arranged to maintain continuous service to each floor and minimize potential for single-point failures or loss of service, including during times of renovation. All double-fed horizontal mains shall include valves to permit sectionalizing for alterations and repair.

Horizontal distribution mains for pressurized services shall be located on the floor or within the interstitial space above the floor where equipment or fixtures are to be served. Horizontal distribution mains serving each floor shall be independently connected to supply risers, and shall not serve fixtures or equipment on other floors through branch lines upfed or downfed through a floor slab. The distribution arrangement shall ensure an entire floor may be shut-down without affecting fixtures or equipment on other floors. Where pressurized services are looped or arranged as double-fed mains to maximize reliability, sectionalizing valves shall be provided such that a branch or portion of the piping serving an individual lab and individual floors may be shutdown without disrupting the service to the entire floor, other floors, or building areas.

Service pipe runouts shall be placed at regular intervals in service shafts or utility corridors to ensure accessibility for future connections with minimum disruption to research programs in adjacent spaces. Runouts shall be valved and capped. All piping stubouts to fixtures and equipment should be rigidly braced to structure.

Piping shall not be or routed above major electrical, telecommunications, or other critical equipment (including service access for such items), and shall avoid such rooms unless serving such spaces. Only with prior NIH ORF approval and where other options for rerouting are not feasible will monitored double containment piping systems be considered. The use of drip pans is not equivalent. Piping shall not be buried below the floor under major electrical rooms, telecommunication service entrances, or other critical spaces where need to excavate to repair or renovate such piping would introduce otherwise unnecessary operational disruption, safety or security hazards. In as much as possible, piping shall not be buried under slabs directly below major mechanical, research or vivarium/ cagewash equipment or where otherwise inaccessible without causing undue disruption.

## C.3 Valving and Access:

Isolation valves shall be provided to accommodate easy maintenance at each module, laboratory, group of toilet rooms, program suite, or other distribution lines where routine service shall be required without affecting other areas. Isolation valves shall be accessible and located on the floor being served or in the interstitial space serving the respective program area. All valves shall be clearly identified (labeled/tagged), and correspond to the facility valve numbering and identification system, keyed to submitted charts. Each fixture and equipment item (with the exception of individual turrets that are not part of a capture device) shall be provided with an individual isolation valve or fixture stop. Drains shall be provided at the base of all water risers and include NPT threads, valve, and cap.

Space shall be provided for accessibility to permit modifications and maintenance to the system. Equipment shall include, but not be limited to, valves, cleanouts, motors, controllers, and drain points, etc. Where required, access doors or panels shall be provided.

## C.4 Materials:

Piping, fittings, and joint materials and methods shall be compatible with system application and specified in accordance with Exhibit X 6-3-A. Piping Materials in the HVAC Chapter. All plumbing piping systems shall be identified using pipe labels as required. See HVAC Chapter 6 Section 6-9 “System & Piping Identification and Materials”.

Where renovations occur in existing facilities and especially where taps are made into existing systems, it is preferable to match existing piping materials in as much as possible so long as the materials and joint methods are in conformance with the requirements of Exhibit X 6-3-A.

The selection of materials and installation methods shall incorporate special requirements unique to individual program areas, such as consideration of magnetic fields, special materials, shielding, also all types of chemical exposure etc. in accordance with equipment and functional operation requirements. Also see "Stainless Steel Trap Corrosion" document on our web site: http://orf.od.nih.gov/PoliciesAndGuidelines/Bioenvironmental/

## C.5 Penetrations:

Floor penetrations shall be minimized, and all penetrations shall be appropriately sealed and caulked to prevent leakage and maintain the fire rating of the slab. Pipe sleeves shall be provided at all penetrations through floors, except that pipe sleeves are not automatically required for underground buried piping passing through the lowest building floor slab on grade, unless otherwise necessary for corrosion resistance or to prevent moisture infiltration. Pipe sleeves shall extend a minimum 50 mm (2 in.) above the floor and 13 mm (1/2 in.) below the floor and shall include a built-in water stop and appropriate seal.

In existing facilities renovated to accommodate new lab program, the A/E should be diligent to seal existing penetrations. The use of expandable pressure-plate type mechanical link sealing devices (that meet fire/smoke stop requirements) is often recommended for cases where a raised pipe sleeve penetration would prove impractical in existing installations.

## C.6 Noise and Vibration:

Equipment and piping installations shall be designed to preclude noise and vibration transfer beyond referenced limits, including but not limited to use of resilient supports, vibration dampening equipment bases, flexible connectors or braided hoses as appropriate, and other considerations as required for the intended operation of the facility. The A/E shall consider maximum acceptable noise and vibration criteria in each equipment selection, location, and system design. Where flexible connection devices are utilized (whether for accommodation of noise, vibration, or movement due to expansion and contraction), the selected device shall be specifically compatible for use with the fluid system contents, including cleanliness, purity, materials and elastomer selection, maximum temperature and pressures. The A/E shall ensure appropriate application of control units with flexible connectors and proper system anchorage. Refer to the HVAC Chapter for additional details related to specific noise and vibration limits.

## C.7 Utility Metering:

Utility metering shall be provided for primary utility services, capable of automatically registering peak flow and totalization to NIH building automation utility monitoring systems. Meters are provided for steam make-up to water heaters only where required by the program or requested by NIH.

# 8-1-10 Design Guidance

## A. Overview:

The plumbing systems at the NIH are categorized as domestic potable water plumbing systems, industrial non-potable laboratory water plumbing systems, laboratory gas and vacuum systems, fuel systems, vivarium systems, medical gas systems, various types of pure water systems, and various process piping systems.

Plumbing requirements are often dictated by user and program requirements during the design phase. These are subject to change because of improving equipment technology and the need to remain state-of-the-art when the construction process is completed. The A/E shall clearly understand the wide range of utility requirements necessary and design flexible distribution systems to support future connections.

Plumbing systems shall support the needs of the building occupants; be easily maintained and operated, have reliable and redundant components; and be efficient to operate. Typically each facility will have numerous piping connections which shall be concisely detailed and engineered in the contract documents to suit the applications intended to be supported or serviced.

## B. References:

The A/E design firm shall use and comply with the design and safety guidelines, and references listed in Appendix A as well as other requirements received or directed from the NIH Project Officer or required by the program. The A/E shall utilize the latest editions of referenced design and safety guidelines available at the time of the design contract award.

Plumbing systems shall meet the requirements of the current edition of one of the three national model plumbing codes, in addition to written requirements of the NIH DRM. In cases of conflict between the adopted or selected code and the NIH DRM, the most stringent, technically appropriate, and conservative criteria shall apply. The code is typically a minimum standard, and in most cases the DRM is most stringent. Where it is unclear which criteria is to be applied, application for clarification may be made to the project officer. In cases where the DRM specifically allows a practice lesser than that required under a national model code and the project is located external to the Bethesda Campus, an application for clarification should be made to the project officer. Plumbing fixture count shall comply with the requirements of the local adopted building code, which at the Bethesda and Poolesville Campus is the International Building (IBC) and International Plumbing (WSSC version) Code.

The three recognized national model plumbing codes are:

- International Plumbing Code, International Code Council
- Uniform Plumbing Code, International Association of Plumbing and Mechanical Officials
- National Standard Plumbing Code, National Association of Plumbing, Heating, and Cooling Contractors

Note: Requirements within the same system shall not be blended between codes where such would compromise the code intent. For example, drainage and vent pipe sizing and required system vent locations as affected by system arrangement shall not be intermingled.

Fuel gas piping shall meet the requirements of the most current edition of the International Fuel Gas Code and NFPA-54. Where alternative fuel gas systems are permitted (other than natural gas), compliance with the associated NFPA standard, IBC, and NIH DFM requirements are mandatory.

All wastewater discharges into the Washington Suburban Sanitary Commission (*WSSC) sanitary sewer system* shall conform to the industrial wastewater discharge parameters of the (Latest) WSSC Plumbing & Fuel Gas Code.

Process and specialty piping systems shall comply with the requirements of the DRM, as well as ASME Standards, CFR (US Code of Federal Regulations), and industry consensus standards as well as requirements of other regulatory agencies as deemed applicable or pertinent by the NIH or the A/E in agreement with the NIH.

In addition to requirements for conventional plumbing and process piping systems, there are specific industry guidelines and standards that should be followed in concert with the NIH Design Requirements Manual, as well as specific requirements that may be required by the program or received from the NIH Project Officer. Applicable requirements of the following organizations are generally mandatory, unless otherwise waived or directed herein:

- American National Standards Institute, (ANSI), Washington, DC 20036.
- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), Atlanta, GA 30329
- American Society of Mechanical Engineers (ASME International), New York, New York, 10016

- American Society of Plumbing Engineers (ASPE) Technical Data Books, Chicago, IL 60656
- American Society of Sanitary Engineers (ASSE), Bay Village, OH 44140
- American Society of Testing and Materials, (ASTM International), West Conshohocken, PA, 19428
- American Welding Society (AWS) Miami, FL 33126
- Compressed Gas Association (CGA), Arlington, VA 22202
- Food and Drug Administration (FDA), Rockville, MD 20853
- Instrument Society of America (ISA) Research Triangle Park, NC 27709
- International Code Council (ICC), Washington, DC 20001
- International Association of Plumbing and Mechanical Officials (IAPMO), Ontario, CA 91761 -USA
- National Association of Corrosion Engineers (NACE), Houston, TX 77218
- National Sanitation Foundation (NSF), Ann Arbor, MI 48106
- American National Standard for Emergency Eyewash and Shower Equipment (ANSI Standards Z358.1): American National Standards Institute (ANSI).
- Planning and Design of Laboratory Facilities: Baker, J. H., Houang, L. (1983) the World Health Organization (WHO), Offset Publications, 72: 45-71.6.
- Occupational Safety and Health Standards, CFR 29, Part 1910: U.S. Department of Labor, Occupational Safety and Health Administration, (OSHA). Telephone 202-783-3238.
- Guidelines for Research Involving Recombinant DNA Molecules: U.S. Department of Health and Human Services, U.S. Public Health Services, National Institutes of Health, Federal Register/Vol. 51, No. 88: 16957-16985, Bethesda, MD: National Institutes of Health. Telephone 301-496-9838.
- Laboratory Safety Monograph: A Supplement to the NIH Guidelines for Recombinant DNA Research, U.S. Department of Health and Human Services, U.S. Public Health Service, National Institutes of Health Bethesda, MD: National Institutes of Health. Telephone 301- 496-2960.
- Guidelines for Laboratory Design: Health and Safety Considerations: DiBernardinis, L., and J.S. Baum, M.W. First, H.T. Gatewood, E.F. Gordon, and A.K. Seth. 1987. New York: John Wiley and Sons.
- Biosafety in Microbiological and Biomedical Laboratories U.S. Department of Health and Human Services. Washington, DC: Public Health Service, Centers for Disease Control, and National Institutes of Health, HHS Pub. No.(NIH)88-8395. Telephone 202-783-3238.
- NIH Guidelines for the Laboratory Use of Chemical Carcinogens: U.S. Department of Health and Human Services, Bethesda, MD: National Institutes of Health, NIH Pub. No. 81-2385. Telephone 301- 496-2960.
- National Fire Codes, all volumes: National Fire Protection Association, (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101, Telephone 617-770-3000.

- Guide for the Care and Use of Laboratory Animals: U.S. Department of Health and Human Services, Bethesda, MD: National Institutes of Health, Pub. No.86-23, Telephone 202-783- 3238.
- Medical Laboratory Planning and Design: College of American Pathologists, Skokie, IL. Telephone 708-446- 8800 Ext. 531.
- Uniform Federal Accessibility Standards, FED STD 795
- The Americans with Disabilities Act Accessibility Guidelines•

The A/E shall be cognizant of additional requirements in other sections of the DRM. Many requirements related to plumbing systems are common with HVAC, and may be found in the HVAC chapter (Section 6). For example the requirements for piping and joint materials, pipe and valve identification, vibration and noise isolation, and insulation may all be found in Section 6.

# 8-1-30 Design Document Requirements

## A. Plumbing Document Requirements

All pressurized piping systems shall be provided with flow arrows on drawings to indicate direction of process flow. Each system shall be represented with distinct nomenclature to promote legibility and the nomenclature should correspond with piping tagging and identification text. All gravity drainage piping drawings shall be provided with indication of the required installed slope and sufficient notations of piping invert elevation. A separate plan shall be provided to indicate buried plumbing systems, and piping systems installed above the floor shall not be shown on the underground plan. All underground plans for buried piping shall show foundation footings, respective grade beams, as well as the floor plan, partition layout, room names/type, and significant equipment/furnishings to be installed on the floor located on grade. Typical plumbing floor plans shall indicate partitions, room names/type, and significant equipment/ furnishings for the same floor on which the piping is located. MEP equipment room plans shall clearly indicate service access and traffic aisle space, as well as locations or outline of significant equipment for other disciplines. Plumbing schedules shall specifically identify equipment and fixture connection requirements as well as equipment/appurtenance design capacities and correct adjustment of significant operating parameters. The required pressure adjustments and flow rates for devices such as balancing valves, pressure reducing valves, booster pump controls, and similar field adjustments shall be indicated on drawings or within drawing schedules. Sufficient detail shall be provided in drawings and schedules to clearly indicate system requirements, and in general, systems shall not be so generic as to require contractor or vendors to perform professional design tasks. A detailed legend sheet shall be provided for all plumbing line types, abbreviations, symbols, and instrumentation utilized.

All piping, including sanitary and lab waste lines, shall be indicated on the plan of the floor for which the piping is actually to be located. Floor drains and buried structures for the lowest on-grade slab shall be shown and called out on the underground plan, and drain tops shown on the respective floor plan. Riser diagrams shall be provided for all plumbing/ piping systems for buildings over one story in height, and for all facilities operating at BSL-3 or above, and where otherwise required to clearly communicate design intent and necessary detail. Fixtures/ equipment callouts shall be indicated on riser diagrams, as well as either room numbers, reference lines, or other means to permit rapid interpretation of riser to the corresponding plan area. Plumbing plans for above ground systems in lab, vivaria, kitchen, and mechanical room spaces shall generally be shown at a scale of not less than ¼ in.=1 ft. and underground systems at a scale not less than 1/8 in.=1 ft. Plans depicting process fluid systems (including vivaria and medical gasses) shall be shown on separate plans from the

conventional water, waste, fuel gas and storm, except shared plans are acceptable with an appropriate scale of not less than ¼ in.=1 ft.

Plumbing connections to laboratory, medical, food service, vivaria and other specialty equipment shall be fully detailed on drawings and in conformance with the requirements of the DRM. The A/E shall not rely on space and equipment consultant planners alone to ensure appropriate engineering systems or proper system connections.

Where specialty process systems are provided, the design shall include PFD (Process Flow Diagrams) and P&ID's (Process and Instrumentation Diagrams) for prior review by the NIH. Preliminary operational and key control sequence descriptions shall be provided along with PFD diagrams, as appropriate depending on system complexity and necessity to adequately convey key information and salient features design review. P&ID's shall include a full written sequence identifying key operational, control, and safety elements with instrumentation detailed in accordance with ISA standards. In some cases it is understood final P&ID's may not be generated until after the contract is awarded, however in such cases, final P&ID's shall be submitted for review and approval prior to procurement, consistent with PFD concepts as approved by NIH.

The design documents shall thoroughly communicate system engineering requirements, and in general, the A/E should not leave engineering activities up to the discretion of contractors and vendors. This is not intended to preclude the assembly of primary manufacturer-engineered and assembled equipment, provided such arrangements comply with the DRM and that the design documents are provided with sufficient detail that NIH may confirm acceptability of the proposed arrangement during design document reviews. In certain cases, the NIH project officer may require addition submission of detailed drawings of vendor-arranged systems for concurrence prior to procurement. .

The A/E shall include in the project specifications that all systems shall be tested and inspected for conformance with the contract documents and the DRM. Each plumbing installation shall be inspected, signed off, and thoroughly tested prior to concealment. Plumbing work shall be reviewed for proper slope, joints, layout, materials, and installation. Testing shall be provided for all systems and witnessed prior to backfill, concealment in walls, and again at final completion. All installations shall be tested and inspected by qualified inspectors to at least the same degree as would be required for an installation off campus. Final inspection tests shall confirm proper installation and adjustment, code compliance, completeness, omission of cross connections, and leakage. The engineer shall include in the specifications, that systems installation shall be performed by qualified personnel with either a state or local jurisdiction licensure and all required qualifications, appropriate for the type of work performed.

## B. Specific Submission Requirements

Plumbing Documents shall comply with the requirements listed in Appendix B "Architect-Engineer (A/E) Checklist of Services" as stated for the different phases of the particular project. Projects phases may vary from project to project. Typically, project phases include: Pre-design, Schematic, Design Development, Construction Documents, and Construction Administration.

### B.1 Pre-design Phase:

The pre-design phase shall include a detailed and project-specific basis of design technical narrative and preliminary system diagrams (flow diagrams). The basis of design narrative shall be sufficiently detailed to convey the system intent (e.g. general description, areas served, significant features). The copy of preliminary calculations and preliminary cost estimate shall be included in this submission.

### B.2 Schematic Design Phase:

Drawings shall show the arrangement of utilities, major services in and out of the building primary distribution paths, shafts sizing, MEP equipment room size, location, foot prints and access for service and replacement of MEPF Equipment, and preliminary Bases of Design (BOD), Flow Diagrams, incorporating NIH design directions and comments from the Pre-design Phase. In addition, preliminary calculations for sizing of key system equipment and primary infrastructure as well as key technical reports and analysis must be submitted at this phase. Preliminary riser diagrams should be developed to show key elements and distribution concepts for each program area.

The outline specifications shall be included, as well as updated calculations and cost estimate.

### B.3 Design Development Phase:

At the DD Submissions, document development shall have appropriately progressed and each submission must pick up or address all prior review comments. The first DD submission should include comprehensive riser diagrams and details, and completion of NIH design review comments. The second DD submission should be essentially complete, including final calculations and all previous NIH design review comments, leaving the final submission to only pick-up final minor details and final comments. An updated copy of all calculations, project specifications, and the basis of design narrative shall be included in each submittal. Project specifications shall be appropriately developed into detailed project-specific documents and updated for each submission. In addition, energy considerations and life-cycle cost analysis, updated cost estimates, preliminary construction phasing plans,

control diagrams and draft commissioning documents shall be provided with all other documents indicated in other sections of the DRM.

## B.4 Construction Documents Phase:

The Construction Documents shall include an updated and complete final basis of design narrative including final calculations, key reports and analysis, as well as the final energy model and life cycle analysis organized and bound suitable for use as project record documents. All previous NIH review comments shall have been incorporated or resolved to NIH satisfaction. Drawings shall be complete including fully sized riser diagrams and system diagrams for all systems and utilities, fully sized piping on the floor plans, equipment lay out and details, coordination of service access and major equipment egress/replacement paths, control diagrams, final P&IDs, construction phasing plans, final specifications including controls and commissioning, final cost estimate, and other documents indicated in other sections of the DRM.

## B.5 Construction Administration Phase:

Construction Administration typically includes: shop drawing review, provision of responses to Request for Information (RFI) and drawing clarification requests, site visits and inspections, equipment start-up, participation in the commissioning process, punch list development, and other activities as required by the contract.

### B.5.1 NIH Review of Contractor's Submittals:

NIH reserves the right to review any and all contractors' construction and equipment submittals. At the NIH Project Officer's request, copies of contractors' submittals may be required for NIH's review and concurrence. This is especially true in the case of critical equipment or for systems where detailed P&ID and associated data deferred from initial A/E design. The A/E shall incorporate any and all NIH review comments in the contractor's submittal and the as built final documentation package.

## B.6 Guidance for the A/E:

### B.6.1 Cost Estimates (Systems and Quantity Takeoff Estimates)

Systems cost estimates shall be developed at design development stage and quantity take-off estimates shall be developed at the contract document stage. The criteria for quantity take-off estimates may vary as it is described in the POR.

### B.6.2 Calculations and Analysis

Each plumbing design submittal shall include, but not limited to the following design calculations, diagrams and analysis:

Connected and/or demand load
Riser diagrams for each system
Storm water calculations
Equipment and Distribution Sizing, flow and pressure calculations
Process System P&IDs
Materials adequacy/compatibility analysis

## B.6.3 Contractor's Requirements:

Project construction specifications shall require the contractor to provide the following:

- Contractor shall provide startup, testing and operation verification for all equipment provided in the project.
- Contractor shall provide owner training for all equipment provided in the project. This shall include testing, operation and maintenance. Training shall be video taped for future training sessions. Copy of the DVD shall be turn into the Project Officer.
- Contractor shall provide complete Operation & Maintenance (O&M) manuals for all equipment provided in the project. This shall include copies of all equipment related shop drawings, and copy of all warranties and guaranties with the appropriate manufacturer contact information. An electronic copy, CD or DVD format, shall also be provided. Scanned copies are not acceptable.

# Section 8-2: Plumbing Fixtures



## 8-2-00 Design Requirements

Plumbing fixtures at NIH facilities typically include conventional domestic plumbing fixtures, fittings, and trim, as well as items that may be unique or specifically designed for use in laboratory, vivaria, and other specialized program areas. In some cases, plumbing fixtures are components of other lab equipment (e.g. fume hood cup sinks, gas turrets, etc.).

A variety of specification techniques are utilized by various A/E firms, especially with regards to placement location/ specification division in which individual items are specified, (especially specialty equipment). Regardless of where specified, the requirements of the plumbing section of the DRM apply to devices connected to the plumbing system and should be coordinated between the plumbing specifier and any other specification writers that may specify components requiring plumbing services.

Items shall be selected which aid in maintenance of the aseptic environment. Plumbing fixtures shall be selected in accordance with applicable national standards to provide appropriate function, durability, quality, and ease of maintenance. The A/E shall consider sanitation, durability, and potential for cross-contamination in selection of plumbing fixtures, which shall be made of nonabsorptive, acid-resistant materials.

## 8-2-10 Design Guidance

### A. Water Closets:

Water closets shall be wall mounted, 4.0 to 5.0 liter per flush (LPF) (1.0 to 1.28 gallon per flush (GPF)), siphon jet type; with electronic hands-free flushometer that is hard wired on stand-by power. Battery-powered operation is not accepted. The use of manual flushometers is generally discouraged, but may be approved on a case-by-case basis for non-public, non-food service areas. The use of flushometers that provide dual flush volume on water closets that are designed for 6 LPF (1.6 GPF) is NOT acceptable due to potential compromise of the trap seal under varying flush conditions, and also due to increased

stoppage potential due to the reduced water volume and hydraulic depth for waste transport in the downstream piping system.

Water closets shall be provided with commercial/institutional grade closet carriers with dual feet plus an auxiliary anchor support; and institutional weight open front seats furnished less cover and with heavy duty stainless steel check hinges.

## B. Urinals:

All urinals shall be wall mounted, 2.0 to 3.0 LPF (0.5 to 0.8 GPF), and of the siphon jet or blowout action type, with electronic hands free flush, hardwired on stand-by power. Battery powered operation is NOT accepted. Washout urinals and waterless fixtures are not permitted. The use of manual flushometers is discouraged, and may be approved only on a case-by-case basis for non-public, non-food service areas.

## C. Lavatories and Sinks:

Lavatories and sinks shall meet the following criteria:

- Wall mounted lavatories shall be vitreous china or stainless steel with an integral back splash, provided with specifically designed and manufactured carriers. Where carriers cannot be provided due to type of fixture, the fixture shall be bolted to the structure.
- Counter-set lavatories shall be enameled cast iron or stainless steel except where integral to the counter top.
- Electronic hands-free faucets with arc or gooseneck spouts, hard wired and on stand-by power shall be provided for lavatories in restrooms. Battery-powered operation is not acceptable. Laboratory sinks shall be rated for a water flow of 8 L/min (2 GPM). Restroom's lavatories with other than metering faucets shall be rated for a water flow of 1.5 to 1.9 L/min (0.4 to 0.5 GPM). Restroom's lavatories with metering faucets shall be rated for a water flow of 0.8 to 1 L/min (0.2 to 0.25 GPM). The cycle time (metering faucet) for restroom's lavatory faucets shall be adjusted to maintain water conservation at not more than 1 liter per cycle (0.25 gallons per cycle).
- Wrist-blade gooseneck faucets with a maximum flow rate based on current Federal EPACT requirements may be provided in public restrooms on a case-by-case basis for non-food service areas. Automatic sensor faucets are preferred for sanitation.
- Lavatories and handwash sinks in vivarium and all process areas shall be constructed of stainless steel. Type 304 is adequate for dedicated handwash sinks. Stainless steel sinks in vivaria, cage wash, and wherever subject to impact shall be not less than 16-gauge.
- General hand wash faucet actuation shall be wristblade, slow-close foot pedal, or electronic sensor type, hard wired and on stand-by power. Electronic sensor or slow-

closing foot pedal actuation is required for critical handwash applications. Procedure, Necropsy, and similar spaces should use hands-free faucets.

- Handwash sinks shall utilize gooseneck or high-rise spouts, with the spout outlet not less than 130 mm (5 in.) above the fixture rim.
- All stainless steel sinks used in cagewash areas and laboratories with the exception of dedicated handwash sinks, shall be of Type 316 material.
- Self-rimming/drop-in and under-mount lavatories and sinks shall be bedded in sealant before fixture is set, and caulked upon completion.
- Specifications for self-rimming/ drop-in sinks shall require fixtures that can be securely fastened to the counter top with mechanical-type fasteners that clamp the sink basin to the deck with a screw-type clamp fastener. The use of snap-clip type installation systems are not permitted.
- Sinks for surgical prep spaces (such as vivarium surgery areas) shall be hands-free, through use of either knee panel or electronic sensor faucets, hard wired and on emergency power and fitted with either rose spray or non-aerating laminar flow outlets of at least 10 l/min (2.5 gal/min).
- Laboratory sink faucets shall be provided with integral vacuum breaker gooseneck spouts.
- Aerating stream faucets shall not be used for faucets in clinical areas including vivaria. Laminar flow outlets of at least 8 l/min (2.0 gal/min) are required, except serrated tips may be furnished where necessary.
- Faucet spout reach shall be appropriate to sink size, and spout shall be swing or rigid type as suited for the application.

## D. Showers:

Shower control valves shall be of the thermostatic or combination thermostatic and pressure balance type, except that shower controls that are of the pressure-balance only type will be permitted for applications where the upstream hot water supply includes duplex master thermostatic mixing valves (arranged in parallel to provided continuous thermostatic protection throughout the flow range), and where there are no supplemental energy sources that could otherwise negate master thermostatic protection. Showers shall be rated for a water flow of 8 L/min (2.0 GPM).

Maximum outlet temperature at showers shall be limited to 45 degrees C (112 deg. F) at the individual fixture limit stop. Shower valves shall be institutional cycling type, rotating through cold to hot with an ADA compliant lever handle. Faucet trim, levers, and escutcheons shall be constructed of stainless steel or chrome plated brass, and all shower valves shall include check stops.

All showers shall be provided with a floor that includes a positive slope toward the drain. Shower drains traps and piping shall be a minimum of 50 mm (2 in.) diameter, except 75 mm (3 in.) shall be used where the drain also serves as room floor drainage. Where showers are built-in-place, a chlorinated polyethylene liner shall be provided and properly installed with a positive preslope to the drain clamping device. Alternative water proofing that is at least equivalent to a sloped CPE safing installation may be utilized, subject to approval of NIH. Where hand showers are provided, trim shall be substantially durable for institutional use and all hangers and slide bars shall be securely anchored to the building structure. The inlet hose serving hand-showers shall include an ASSE 1014 backflow preventer or vacuum breaker, mounted to the wall.

## E. Emergency Showers and Eyewash:

At least one emergency shower and eyewash shall be available to each laboratory space/area where hazardous materials are handled (such as a chemical fume hood, chemical storage, and other similar activities). At least one eyewash station shall be provided in each laboratory space and shall be located so as not to exceed 17m (55 ft.) from any point in a laboratory, and the A/E shall consider providing an eyewash fixture at each lab sink. Emergency eyewash and shower fixtures shall be provided in cagewash areas nearest where cleaning chemicals are handled and dispensed, medical/pathological waste areas, pH treatment rooms, hazardous material and chemical storage areas, and other areas where hazardous chemicals are utilized or otherwise deemed necessary through consultation with DOHS. In spaces where a significant hazard exists and it is likely a user may be present without supervision, a flow alarm shall be provided to indicate emergency shower operation. Locations where this may be necessary shall be determined through DOHS, and may include areas such as chemical storage and pH treatment system rooms. The location of emergency shower fixtures shall be approved by DOHS and shall generally be within 10 seconds' reach along an unobstructed pathway (i.e., no doors without panic bars or which do not swing open when pushed) by the laboratory occupants from the hazard.

All laboratory safety equipment shall meet the requirements of ANSI and OSHA safety and health standards. Water tempering is not required for emergency fixtures installed indoors at the Bethesda and Poolesville campus.

Emergency shower and eyewash fixtures shall be served from potable cold water systems and incorporate backflow protection and proper identification to safeguard the potable water supply. New facilities shall include potable water distribution with ASSE 1013 backflow protection to serve emergency fixtures as required, however in existing facilities where adequately flushed potable cold water is not readily available, laboratory water may be

extended from the nearest adequately sized riser. Provision of a dedicated emergency fixture water distribution system throughout the entire building is not required. It is acceptable to connect from an adequately sized potable cold water riser serving each floor with a backflow preventer. Identification of piping downstream of the isolating backflow protection as “Emergency Fixture Water” shall be provided. The provision of the central backflow preventer for water supply serving the emergency fixtures should not be construed to deem the water supply to emergency fixtures as non-potable, but rather is applied as enhanced protection for upstream supplies from unauthorized tappings of distribution lines or improper device application that even against best practices and safegaurds can occur in a large lab facility. Emergency fixtures shall each be provided with an accessible indicating shut off valve either locked open or exposed at the fixture.

The A/E shall carefully consider the location and routing of the water line to minimize dead-legs and potential for stagnation and fouling. Where possible, the end of the emergency fixture water main at each floor shall serve at least one commonly used cold water fixture of adequate use and volume, preferably a single flushometer water closet. Multiple sinks or similar fixtures may also be used, so long as they ensure sufficient turnover of the water supply. In cases where there is no suitable normally used cold water plumbing fixture on the floor served, the A/E shall provide a time clock-actuated line purge at the end of the supply main for the floor, which shall discharge to an indirect waste receptor at a rate of at least 57 l/min (15 gal/min) or as necessary to provide a 0.6 m/s (2 fps) velocity in the main for sufficient duration to turn over all contents in the water line on a bi-weekly basis. The A/E shall plan the location of the water main above the labs or in service corridors, providing a loop as necessary to minimize length of run-outs to fixtures and maximize flexibility. The horizontal distribution loop and end of line purge for emergency fixture supply mains shall be independent to serve only a single floor and building wing, such that each floor and building wing can be independently isolated for maintenance or renovation, allowing for continuous normal service to other areas of the building.

Piping serving emergency fixtures shall be of adequate size to supply the maximum quantity of emergency fixtures to be in simultaneous use, but not less than the flow rate of the single most demanding emergency fixture plus the total simultaneous flow of the flushing purge fixture. In most cases, this will require the distribution main to be 38 to 50 mm (1-1/2 to 2 in.)diameter, based on an emergency shower fixture of 75-115 l/min (20-30 gal/min) and a flush-o-meter purge fixture flow rate of 75 to 130 l/min (20 to 35 gal/min). The minimum size branch line to a single emergency shower is 32 mm (1-1/4 in.), and a 13 mm (1/2 in.) branch shall be provided to serve each emergency eyewash. Flow velocity under conditions of maximum design simultaneous use may be up to 3 m/s (6 ft/min) in the main. However residual pressure at the outlet shall not be less than 210 kPa (30 psi). The maximum simultaneous use demand shall be considered in sizing of piping, equipment, and

simultaneous pump capacity, with the exception of building water services already sized to supply other emergency demands (such as fire protection).

Emergency shower and eyewash fixtures shall be of the on-off type, operable with a single hand under partially distorted vision, with valves designed to remain open upon initial operation until manually turned off. Eyewash units shall be capable of irrigating both eyes at the same time. Eyewash facilities shall be installed with pressure regulators as necessary to prevent injury due to water pressure and provide proper flow control, as well as incorporate sediment screens. Where eyewash fixtures are provided at sinks, they should be arranged with special attention to the selection and location of the fixture so as not to conflict with sink operating controls or needed counter space. Eye wash fixtures shall not be built-in or attached to laboratory faucets.

Drench hose and swing out type eyewashes are the preferred type in NIH laboratories. In choosing the appropriate type, the designer must ensure that the fixture is properly located for its intended use; that the fixture has minimal impact on adjacent counter space; and that the water stream is directed toward the sink bowl to encourage frequent flushing.

Where drench hose-type emergency fixtures are utilized, the unit shall incorporate a dual check laboratory backflow preventer with intermediate atmospheric vent (such as an ASSE 1035 device) that is located at the inlet of the fixture hose.

## F. Janitor Sinks:

Janitor mop sinks and service sinks shall be constructed of enameled cast iron or stainless steel and be fitted with drains not less than 75 mm (3 in.) diameter.

## G. Drinking Fountains:

Drinking fountains shall be stainless steel, wall mounted fixtures. Electric chilling is generally required for Bethesda Campus or Poolesville projects.

## H. Hose Bibbs/Hydrants:

Hose bibbs shall be provided within mechanical equipment rooms, kitchens, loading dock areas, and within planters for watering. Wall or yard hydrants shall be provided outside the building to accommodate landscape watering, pavement/ sidewalk cleaning, and loading dock cleanup. All exterior hydrants shall be freeze-proof design. All hose bibs/hydrants shall be provided with integral hose bibb vacuum breakers, and shall be self-draining type where subject to freezing.

## I. Trim:

Fixture stops serving lavatories, sinks, and similar fixtures shall incorporate threaded inlets. The use of compression fittings is undesirable; however, a single compression connection at the downstream side of the fixture stop may be provided, except for foot or knee pedal-operated valves. Fixture stops shall be of the heavy-duty commercial grade type and shall be the loose-key type in public areas. Fixture trims shall comply as follows:

- Traps, drains, and tail pieces for general domestic sinks and lavatories connected to the sanitary drain system shall be 1.468 mm (17-gauge) cast brass. Sink strainers and drains shall be stainless steel or chrome plated cast brass.
- Drain and trap connections exposed or within casework for laboratory sinks, fume hoods, and similar equipment shall be mechanical joint type to the trap outlet, using corrosion resistant materials to match the lab waste piping system. 316 stainless steel may be used for drains and tailpieces.
- Stainless steel type 316 sinks shall have stainless steel 316 drains and corrosion resistant traps to match the lab waste system.
- Brass, copper, steel, and cast iron drains and traps shall not be permitted for fixtures or drains receiving discharge from high-purity water outlets, blood analyzers, or aggressive discharges.
- All connections downstream of the laboratory fixture trap shall be as specified for laboratory waste systems.
- Piping to plumbing fixtures shall be supported and anchored to the structure, not the fixture.
- Exposed offsets of trap arms, extensions; excessive tailpiece, or supply length from rough-in shall be avoided by proper rough-in location.
- Independent water isolation valves or supply stops shall be provided for each fixture or equipment item.
- Thermostatic mixing valves with check stops shall be provided for fixtures and equipment requiring precisely controlled-temperature water supplies, (for example photo processing).
- Where electronic sensor faucets or sensor flushometers are utilized, a single transformer shall not serve more than one room.

## J. Foot Pedals:

Where foot pedal valves are required, they shall be arranged to mount above the floor in casework or above the floor on anchorage brackets, and shall be provided with extended (long) fold-up pedals. It is preferred that piping be concealed under casework so as not to preclude the use of cabinet space. Where faucets include both hand and foot pedal operations, separate isolation valves shall be provided for the foot pedal valve to facilitate maintenance. Foot pedal valves shall be fitted with slow-close valve mechanisms.

## K. Wrist Blades:

Where two-handle wrist-blade faucets are utilized, ceramic-type faucet valving with brass or stainless steel internal components are preferred over other means of valve closure. Compression valving shall not be used. NIH experiences significant maintenance and utility costs due to compression faucets and wristblade valves that do not maintain handle position without leakage.

## L. Hands-Free Faucets:

Where hands-free faucet actuation is required, approved actuation shall consist of hard-wired sensor faucets or foot pedal valves. Wrist blade controls are not acceptable. Knee valves are undesirable due to maintenance issues, however knee-panel actuated pneumatic scrub sinks are preferred for major surgical prep areas.

## M. Floor Drains:

Floor drains are required where water may likely accumulate and create a hazard, and also where intensive wet cleaning operations are required, including the following areas:

- Kitchen areas, including serving lines.
- Mechanical equipment rooms.
- Toilet rooms with two or more flushometer operated fixtures or water closets.
- Shower or tub room.
- Service corridors.
- Laundry rooms.
- Cagewash areas.

With the exception of toilet rooms, showers, and kitchens, floor drains shall include sediment buckets. Floor drain grates shall be sized and traffic rated for the application, with grates that are fixed or set so as not to slip or deform with anticipated traffic, including consideration of cages, carts, etc. The entire drain shall be corrosion-resistant, smooth, and contiguous with the floor. Floor drains shall have minimum 75 mm (3 in.) diameter outlets, except that drains in cagewash, loading dock, and kitchens shall have 100 mm (4 in.) outlets. Floor drains connected to the lab waste system and all floor drains in cagewash and vivarium areas, as well as floor drains in kitchens and other areas where sanitation is paramount, shall be constructed of stainless steel. Type 316 is required for applications where corrosion resistance is required, such as cagewash and photo processing areas.

Floor drains, floor sinks, and similar penetrations through wet areas above grade shall be protected with a water safing membrane and clamping collar, except where floors are otherwise protected with a safing membrane or approved water proofing system.

## M.1 Floor Drains in Laboratories:

Floor drains shall not be located inside laboratories, however this does not preclude use of indirect waste receptors such as funnel drains and floor sinks at utility areas required for discharge from equipment.

## M.2 Floor Drains in Animal Rooms:

The A/E shall review the need for floor drains with animal facility personnel. Floor drains should be provided in animal rooms only when specifically required by the *AAALAC Guide*. Floor drains may not be required in all animal rooms, particularly those housing rodents. Floors in such rooms can be maintained by wet vacuuming or mopping with appropriate disinfectants or cleaning compounds. If floor drains are used, the floor shall be sloped and drain traps kept filled with water. In addition:

- Non-jetted floor drains shall have a minimum of 200 mm (8 in.) diameter tops and a minimum 100 mm (4 in.) diameter water seal trap.
- Sufficient means shall be provided for clearing waste stoppages, including judicious placement of cleanouts outside animal holding rooms and to serve the main drain line. Where possible, two-way cleanouts outside the animal rooms in the trap arm are more preferable than cleanouts located integral with the drain.
- Drain grates serving floor drains in vivaria spaces shall not slip under pedestrian or cage rack traffic, and shall be adequate for anticipated traffic loading. Drain covers for normally sealed drains shall be of the lockable stainless steel, gas-tight type.
- Deep seal traps and running traps shall not be used unless specifically required by the proposed application.

To prevent high humidity, drainage shall be adequate to allow rapid removal of water and drying of surfaces. The minimum pitch of trench drains is 20 mm/m (2%). In large animal spaces such as dog kennels and NHP areas, jetted drains with tops of a minimum 150 mm (6 in.) in diameter shall be provided less sediment buckets. A flushing rim feature shall be included unless drains are served by end-washed trenches or other means of adequate wash down. Jetted trap flush actuation shall be by adjustable automatic means with manual capability. Drains in animal holding rooms shall be constructed of acid-resistant enamel-coated cast iron or 316 stainless steel. A disposal unit set in the floor is not a satisfactory solution. In-floor water closets, constructed of stainless steel with blowout flush action, rim-wash, and stainless steel bar grate top can be utilized. In the case of flush-rim drains and in-floor water closets, interior drain bodies shall be only funnel or round bowl shaped, and shall completely evacuate solids placed at any point in the receptor. Flat-bottomed or slightly tapered bottom drains are not acceptable. In-floor water closets shall maintain a visible trap seal and sufficiently scour the bowl with each flush. Where separate jetted traps

are utilized instead of in-floor water closets, the trap and jet location shall be specifically designed for the purpose of transporting solids through the waste system, and the use of trap primer tappings for the water jet connection is not acceptable for this purpose. Where flushing devices are utilized, flushometers shall have hydraulic-type actuation, with a pushbutton located in the holding room (or other animal care staff designated location) and an automatic flush operated by a programmable timer. Alternatively, PLC operation with manual and automatic control such as through a vivarium control system may be utilized. When flushing drains or flush devices are employed on drains, access to components shall be maintained.

All drainpipes shall have short runs to the main drains, and if not in use, they shall be capped and sealed to prevent infiltration of sewer gases and other contaminants. Lockable drain covers are often recommended for preventing the use of the drains for disposal of materials that should be cleaned up and removed by other means.

Drain lines serving holding rooms shall be a minimum 100 mm (4 in.) diameter. Drains in large animal holding rooms shall have minimum 100 mm (4 in.) diameter jetted outlets and may require 150 mm (6 in.) outlets for large animals. 75 mm (3 in.) outlet diameter jetted blowout water closets at not less than 17 liters per flush (4.5 gallon per flush) may be used with 100 mm (4 in.) mains for NHP and kennel areas.

Drain types shall be reviewed with users for suitability in individual rooms. The grate design and strainer elements shall provide adequate rodent and insect protection without increasing maintenance on drains or causing frequent blockage.

## N. Trap Seal Maintenance:

Floor drains, floor sinks, and indirect waste receptors often provide a path for sewer gas to enter the building as a result of evaporation of trap seals due to infrequent use. The A/E shall carefully consider the potential for trap seal evaporation and provide automatic trap seal primers to replenish trap seals where necessary. Only electric-type, time clock-actuated trap primers may be utilized. Non-electric-type pressure drop trap primers shall not be used. Providing a faucet near an indirect waste receptor and reliance on damp floor mopping or manual intervention is not an acceptable means of ensuring trap seal maintenance. Floor sinks serving plumbing fixtures or year-round appliances do not require external trap seal maintenance; however, indirect waste receptors serving mechanical equipment shall be carefully evaluated to ensure adequate flow. Floor drains in toilet rooms and mechanical rooms shall be provided with automatic trap seal maintenance. Drain inlet seal devices, mineral oil, and deep seal traps shall not substitute for required automatic trap seal primers. Trap seal primers operating from flushometers serving 6 liters per flush (1.6 gallon

per flush) water closets and urinals shall not be permitted. Lab planners should work with users to ensure a need for cup sinks, rather than specifying without specific need or function, as unused fixtures create unnecessary maintenance and sewer gas infiltration issues due to dry traps.

## O. Deep Seal Traps:

Deep seal traps may be utilized only for areas where it is required to provide additional protection against ambient pressure imbalances between the fixture inlet and atmospheric pressure. The required depth of deep seal traps is specific to the application, but shall be a minimum 100 mm (4 in.) deep from crown weir to the top of the dip of the trap. Sewer drains shall not be located in pressurized air plenums. Deep seal traps are not an acceptable substitution for proper venting or the provision of trap seal primers.

## P. Roof and Overflow Drains:

Provide with sump receivers and underdeck clamps, and adequate free area for rainwater load. Dome grate shall be of aluminum or cast iron construction. Provide a stainless steel raincap on the top of grates for overflow drains to minimize staining of building side walls for any case where overflow drains are not extended to within 0.45 meters (18 in.) of grade.

## Q. Sump and Sewage Pumps:

Sump and sewage pumps shall be municipal duty (lift station) grade, submersible type, and provided with lift rail, lead-lag-alternate controls, and designed to preclude single point failure. Sewage pumps shall pass a 75 mm (3 in.) ball. Effluent pumps for lab waste shall be designed for use with corrosive wastes, municipal duty grade, typically with 316 stainless steel wetted parts, corrosion resistant floats or ultrasonic control, and corrosion resistant accessories. Sanitary sewage basins shall be of acid resistant reinforced epoxy coated sulfate resistant concrete, or an industrial grade plastic sump of either high density polypropylene or fiberglass construction. Basins for lab waste pumps shall be of an industrial strength high density polypropylene or fiberglass encased high density polypropylene construction, double wall for direct burial, or preferably accessible corrosion resistant tank-in-pit arrangement. Basins for sanitary and lab waste from vivaria or cagewash areas, and other effluents carrying slurry or solids shall incorporate a prefabricated benching unit or conical lower sump self-cleaning bottom design, and shall also incorporate an automatic flush system. In lieu of lift stations, pneumatic ejector systems may be utilized for sanitary and lab waste and should be considered especially where excessive solids may be present. Ejectors shall be provided with cast iron receivers for sanitary and 316 stainless steel receivers and wetted parts for lab waste. Sewage and sump pump lift station and ejector arrangements shall be served from stand-by power systems

and designed to provide N+1 redundancy, to ensure reliability and continuous operation for critical components such as pumps, air compressors/air supply, and control arrangements.

Elevator pit sump pumps shall be of an oil-preclusion type except that standard sump pumps may be used for electric traction elevators with no hydraulic oil lines. Where sprinklers are provided in the pit or shaft, the pumps shall be adequately sized to accommodate sprinkler flow of one head. The pump shall include a high water/general fault alarm to the monitored building automation system. The discharge from elevator pit drains and elevator sump pumps shall spill indirectly to the sanitary drainage system though an air break into a hub drain or floor sink that is located in a mechanical room or similar approved location.

## 8-2-30 Design Document Requirements

Plumbing fixtures and equipment shall be clearly labeled on drawings with such detail as to ensure the specific product to be applied at each location is clearly communicated and may be readily understood. Where items are connected to building automation systems, refer to the NIH project officer for additional specific identification or numbering requirements, ensuring concise identification and interdisciplinary coordination.

# Section 8-3: Water Systems



## 8-3-00 Design Requirements

### A. Water Service:

Water to NIH facilities is supplied through an underground grid network to the buildings. The water mains into the buildings serve the domestic potable water, the industrial non-potable/lab water, and the fire protection water systems.

Each lab, animal, and other critical facilities shall be provided with two water services, each sized for total demand and appropriately connected to the campus loop. Water supplies and distribution systems shall be arranged to minimize potential for single point failure or service loss. Supply connections for the redundant services shall be to different mains/points on the NIH supply grid and arranged to ensure continued water supply. At a minimum, the water service to each facility shall be double-fed from the site utility supply grid, with site utility isolation valves arranged to ensure continuous supply from either direction in the event of loss of water from either side of the site water supply system.

Where two completely separate services are provided to a building, they may be combined type with each sized to serve the total domestic water and fire load. Where only a single, double-fed service is provided (non-critical facilities), a separate dedicated fire service that is independent of the domestic water service line shall be provided. Any isolation or shutoff valve in the main line leading to or branch providing water supply for the automatic sprinkler system shall be OS and Y (outside stem and yoke) and be electrically supervised by the fire alarm system.

Upon entry into the building, each water service shall be provided with a service entrance backflow preventer sized for 100% demand load, ASSE 1013 type for domestic water and ASSE 1048 or ASSE 1047 type for fire service as appropriate. Where only a single water service is utilized to supply each system, backflow preventers on the individual service shall be arranged in parallel, sized to provide N+1 redundancy to allow for continuous water supply. Fire service shall split off upstream of domestic water service entrance backflow preventers such that main fire service backflow preventers are not in series with any other

service entrance backflow prevention devices. Downstream of the service entrance domestic water system backflow preventers, the domestic supply main shall incorporate a municipal grade automatic self-cleaning incoming water filtration system (suction/ jet scanner or cyclonic type) with normally closed bypass, to filter particulate down to 80 micron absolute. Small facilities may (at NIH discretion) utilize duplex Y-strainers in parallel (with blow-downs), in lieu of automatic particulate filtration. Intertie between the multiple services shall be made at the main booster pump suction or sub-system header, arranged to minimize potential for single point failure or service loss.

In some cases, water mains through building tunnels may be classified as part of the campus water main supply grid. In such cases, the service entrance backflow preventers to each individual building shall be provided from a dedicated branch taken off of that supply main, so as not to disrupt the bi-directional flow through the supply grid. The A/E shall coordinate with NIH to ensure the water supply arrangement does not compromise the campus distribution system.

An emergency domestic water connection shall be provided for critical facilities, isolated inside the building with a normally closed and locked shutoff valve and check valve, and terminating with a capped threaded inlet(s) at an approved location. The emergency water connection shall connect to the water distribution system on the suction side of booster pumps and downstream of the main building domestic water service backflow preventers to preclude potential backflow into the site supply system. The emergency water connection is not required for non-critical lab or clinical facilities connected with two water services to separate water mains.

## B. Distribution Systems:

## B.1 Description:

A separate and distinct central laboratory/industrial water subsystem shall be provided and distributed throughout the building, isolated from the domestic water system with parallel ASSE 1013 backflow preventers sized for N+1 redundancy. In most cases a booster pump system will be required to meet water pressure requirements, and in such cases the lab water system shall begin with backflow preventers installed as a subsystem on the downstream side of the booster pumps. In cases where water pressure requirements to the most remote outlet may be met without a booster pump, the lab water backflow preventers shall be arranged parallel with the domestic water service backflow preventers, to eliminate the cumulative pressure drop of backflow preventers in series.

Hose bibs and wall hydrants shall be provide at the building exterior, loading docks, accessible roof tops, major mechanical equipment rooms and where otherwise necessary for maintenance and cleaning. Hose bibs at the building exterior shall be frost proof type with the valve seat inside the heated building, and all hose bibs and hydrants shall be anti-siphon type. Vacuum breakers that utilize break-off screws shall not be utilized for exterior wall hydrants in lieu of repairable designs. Stop and waste valves and stop and waste hose bibs shall not be utilized in underground installations such that the open drain port may become a cross connection hazard.

A water supply distribution approach shall be developed that meets all the program requirements of the facility. The use of two segregated distribution systems shall be required for laboratory facilities. A first system consisting of domestic potable hot and cold water is distributed to toilet rooms, food service, and similar domestic or culinary functions. An industrial non-potable hot and cold water system is distributed to general laboratory areas, cage and rack washers, fume hoods, and vivarium hose stations. General use facilities that do not incorporate a primary lab or vivarium function, and off-campus facilities where primary users may be transient students as opposed to professional staff may require single potable water distribution with point of use backflow preventers or point of use signage. In such cases, the A/E shall ensure backflow preventers are selected in accordance with code and device listing requirements, for example lab faucets would require ASSE 1035 devices, and many other applications will require ASSE 1013 protection.

Potable and non-potable water use shall be determined from Table X8-3-A “Water Distribution”. Mechanical make-up water and water serving equipment shall be from either potable or non-potable systems and shall be provided with local backflow prevention.

Water supplies to all domestic plumbing fixtures shall be potable, and supplies to laboratory and vivaria shall originate from the potable supply, separated only by the indicated backflow protection. Potable water shall be connected to all general-use type fixtures, drinking water, food processes, clinical areas, non-laboratory use ice machines, showers, etc. The use of any reclaimed or recycled water system shall require express approval from ORF and DOHS, and shall not be permitted to serve any vivaria usage, laboratory usage, clinical, handwash, or potable system application.

Exhibit X8-3-A Water Distribution

| Domestic Potable Water | Industrial Non-potable/ Lab Water |
|---|---|
| Animal drinking water (w/BFP) | Glassware washers |
| Eyewash/drench showers (Isolated from building potable water supply by an RPZ backflow preventer, before entering a laboratory) | User laboratory equipment |
| Clinical Services | Hose stations |
| Kitchen/pantry/food service | Laboratory (Non-Clinical) Autoclaves |
| Laundry Equipment | Eyewashes & emergency showers in existing building |
| Public Spaces | Ice machine (laboratory use only) |
| Shower facilities | Fume hoods |
| Toilet rooms and Janitor Sinks | Laboratory/process sinks |
| Treatment areas | Downdraft sinks |
| Water coolers and drinking fountains | Cage/rack washer |
| Clinical Areas, Clinical Equipment, Sterilizers, Washers, (w/ local BFP) | Vivarium Holding Rooms (Washing) |

## B.2 Pressure and Flow Requirements:

The water distribution system shall be designed to provide the required flow and pressure for the most hydraulically demanding fixture/equipment, and the system shall be designed to provide at least 280 kPa (40 psi) residual (flowing) pressure at the most remote outlet on the lab water system and not less than 240 kPa (35 psi) residual pressure for the remote fixture on the domestic plumbing system. Water pressure to non-occupied mechanical equipment floors shall be at least 170 kPa (25 psi) on the downstream side of isolating backflow preventers, and may be boosted locally.

A pressure-reducing station shall be provided if required to limit maximum water pressure to 550 kPa (80 psi) at any service outlet. When serving multiple areas or more than three outlets, a minimum of two pressure reducing valves shall be provided in parallel, with a normally closed bypass. Major pressure reducing station valves shall be of the pilot type automatic control valve, municipal grade with stainless steel trim.

Hot and cold water distribution to each area shall be from the same pressure zone, with systems arranged to provide generally balanced pressures between hot and cold systems.

Building water booster pump systems shall incorporate the following features:

- Connected to building standby power.
- Sized and quantity with capacity split for efficient operation under peak demands and minimum design flow
- N+1 redundancy of total demand, including simultaneous design load of emergency fixtures (typically an allowance of 2 to 4 shower fixtures per building, verify with DOHS) with all pumps running.
- Sufficient capacity for at least one emergency shower plus peak load with any pump out of service.
- Lead/Lag/Automatic Alternate with failure logic to maintain operation.
- Arranged to permit service of single pump or controller with all remaining pumps in service.
- A constant pressure bypass (with PRV control) shall be provided to ensure continuous service with the VFD or control panel out of service. Alternatively, a separate alternating pump system may be provided.
- Where VFD's are used, separate VFD for each pump.
- Local control, alarms, and remote general fault alarm to building automation system shall be provided.
- Accumulator tank use may be considered, but is not permitted for clinical applications or cases where legionella of concern.

## B.3 Building Water System General Design Criteria:

Building water systems shall incorporate the following features:

- Distribution systems arranged as described under section 8-1-00 of this chapter.
- Piping systems shall be properly insulated. Cold water systems shall be kept cold and away from heat sources, such as steam piping.
- Pipe mains shall be designed for the maximum calculated flow at the design stage and to provide a 20% allowance for future expansion.
- The system distribution design shall utilize appropriate fixture unit values, with the cold water system mains, risers, and major branches sized on the basis of flushometer system curves.
- Hot water systems may be sized on the basis of flush tank curves.
- Special demands such as equipment shall be added directly to the calculated flow requirements, without diversity, but may incorporate throughput calculations.
- Where a minor cold water branch line or runout serves only fixtures such as sinks, lavatories, etc (no flushometers or high-use volume outlets on the line), the line may be

sized on the basis of flush tank curves, providing it is still connected to a main line that is sized for flushometer and the complete required hydraulic design criteria are met, including velocity and pressure loss limitations.

- With the exception of tempered water to multiple low-flow lavatory faucets served by a common thermostatic valve, a 13 mm (1/2 in.) supply shall not serve more than one fixture. Water pipe sizing shall conform to the requirements in Table B.6.a.1.
- The incoming water service shall be sized to incorporate the criteria of plumbing demand flow rate at a maximum velocity of 2.4 m/s (8 fps), and total plumbing water demand plus fire system water demand at a maximum velocity of 4.9 m/s (16 fps).
- The C-Factor used for the incoming water service calculations shall not exceed 120.
- Fire department hose stream allowances are added at the point where they occur, and plumbing design calculation requirements shall be appropriately coordinated with the fire protection engineer.
- The flow rate of the maximum design quantity of emergency showers and eyewashes shall be included in sizing of water system piping and equipment.
- Water hammer arrestors shall be provided at all quick closing valves and other potential shock sources, including shower faucets, flushometer branches, ends of long branches subject to hydraulic shock, and required equipment connections. Arrestors shall be sized in accordance with PDI guidelines, including upsizing of arrestors for systems operating above 410 kPa (60 psi).
- Mixing valves which present a constant or extended open path for cross-flow of hot and cold water shall be provided with check valves on both hot and cold supply inlets. Examples include thermostatic and mechanical tempering valves, hose stations, and shower valves. Check valves with devices shall include durable stainless steel or brass gates, or a secondary in-line check shall be provided.
- Multi-story buildings shall include pressure gauges on hot and cold water, and thermometers on hot water and hot water circulation take offs from main risers on each floor.
- Shut-off valves for water systems shall utilize stainless steel trim. Ball valves shall be used for sizes 50 mm (2 in.) and smaller, and sizes 62 mm (2-1/2 in.) and larger shall be 3-piece construction. Ball valves shall be full port, and extended stems shall be provided to clear insulation. Main system/ large diameter valves (100 mm (4 in.) and larger) shall be AWWA gate or AWWA butterfly type, with stainless steel disc and trim. All valves shall be suitable for bi-directional flow, as well as for the system test pressure and temperature.

Pipe sizing criteria shall comply with Exhibit X8-3-B.

Exhibit X8-3-B Water Distribution System Pipe Sizing

| Type | Sizing Parameters |
|---|---|
| Copper hot and cold water pipe | 1.8m/s (6 fps) and 2.4m (8 ft) per 30m (100 ft) head loss maximum for mains, 1.8m/s (6 fps) and 3.6m (12 ft) per 30m (100ft) for branches. |
| High-temperature hot water > 62°C | 1.2 m/s (4 fps) and 2.4 m (8 ft) per 30 m (100 ft) |
| Hot water recirculation | 1.2 m/s (4 fps) and 2.4 m (8 ft) per 30 m (100 ft) |
| Softened water | 1.2 m/s (4 fps) and 2.4 m (8 ft) per 30 m (100 ft) |

## B.4 Backflow Protection:

Backflow prevention devices shall be installed in compliance with plumbing code and the device listing requirements. BFP devices shall conform to applicable ASSE Standards or equivalent AWWA and USC FCCCHR Standards. At the NIH, a minimum of a two-step backflow protection approach shall be utilized to protect the potable water supply and maintain fluid quality in each system. Step one shall be "Isolation." This approach consists of thorough analysis of each potential backflow hazard and the application of proper protection at the use point to prevent contamination of the supply system. The preferred method of isolation is providing a proper air gap at the water supply outlet, but may also consist of approved backflow preventers that are appropriately matched to the hazard level and specific application. Special attention shall be provided to devices and use application points with a high potential as a backflow hazard.

The second step in effective backflow protection shall consist of "Containment." Backflow protection applied at this level shall be provided with the assumption that a complete individual system could be potentially contaminated, and the protection device selected shall protect the upstream water supply. This consists of reduced-pressure principal backflow preventers, such as applied to the incoming water service and at the start of subsystems such as laboratory water supply, fire protection, etc. Additional design requirements in effecting backflow protection at NIH include:

- Use of appropriate equipment and materials.
- Proper design of supply systems for sufficient pressure and operation.
- Assessment of the potential hazard at each use point.
- Proper identification and labeling of specific piping system contents and areas served.
- Ensuring the appropriate water supply system is extended and readily available to serve all areas.
- Consideration of location of piping distribution systems relative to program function.
- Connection from the appropriate system to each use point

- Unconcealed and readily accessible location of BFP devices

The installation of each backflow preventer shall be justified by need. The A/E shall consider the annual maintenance and service requirements for testable devices, and ancillary requirements such as drains, trap primers, etc. Project specifications shall include testing and certification of each testable device after installation by a registered cross connection control device tester, prior to acceptance by NIH. Final test reports and a list of device locations, type and service shall be included in project O&M manuals.
NIH lab facilities shall utilize a segregated laboratory water distribution system, independent of potable water. The intent of the separated laboratory water distribution approach is to minimize the need for point of use backflow preventers, drains, and the significant costs and disruption associated with installing, maintenance, testing, and tracking of these devices to maintain effective protection; while still maintaining potable water supplies to required areas and sufficiently clean water for laboratory research and general non-potable demand purposes. This approach is preferred as it also minimizes the potential of an improper tapping into an unprotected water supply serving other building areas. The laboratory water system shall not serve any outlets intended for ingestion, bathing, or pharmaceutical applications for humans or animals; however the system shall still be protected to ensure a sufficiently clean water supply. This includes the use of reduced-pressure principal devices or vacuum breakers at equipment outlets of particularly high hazard or probability of cross connection, but does not automatically mean that a backflow preventer or reduced-pressure device shall be provided at every outlet or to the degree required of a potable, unprotected system.

The hazard level shall be defined and the A/E shall review the potential for backpressure versus backsiphonage, the planned location of the device, the application of valves upstream or downstream of the device, the likelihood and resultant effect of a backflow event, and other factors such as manufacturers' recommendations and USC, AWWA, ASSE, and code requirements as they apply to the degree of hazard and device application, with the intent to minimize unnecessary devices and maintain system fluid quality for the intended purpose. Backflow preventers shall be located where they may be accessed for proper testing. Devices shall not be located in concealed spaces, above ceilings, or where otherwise inaccessible or likely to be neglected. Backflow preventers shall not be located in pits or where they are likely to become submerged. .

Backflow preventers shall be provided with proper service clearances and adequate drainage. Placement and drainage provisions shall consider the potential of some devices to leak or spill under normal operation. Where necessary because of the quantity of water that could be discharged relative to drain system capacity and location of a reduced-

pressure principal device, an automatic shutoff and alarm signal to BAS shall be provided, which activates upon a predetermined minimum flow rate of discharge through the relief valve. Automatic shutoffs shall function independently for each device, shutting off only the single affected backflow preventer, so as to allow continued water supply through the second parallel device in the event of malfunction. Where RPZ devices 50 mm (2 in.) and larger are used, the A/E shall demonstrate that the drainage system can pass the maximum possible flow rate through the relief valve of the device, or shall provide independent automatic shut-off and alarm annunciation to prevent flooding of the building from an open relief valve under peak discharge conditions. The flow sensor positioned on the relief valve discharge shall be designed to preclude nuisance tripping during low flows such as normal spillage. Even where automatic shut-off devices or other provisions are provided, the device shall be arranged to route normal low-flow drainage to an adjacent floor drain.

All low-point drains that are equipped with hose pattern threads and serve any potable water system shall be provided with ASSE 1011 hose bib vacuum breakers and a hose cap. Where a hose bib is provided near any sewage pump, laboratory waste treatment system, or liquid waste decontamination system, the hose bib shall be provided with a reduced-pressure zone backflow preventer.

The provision of backflow protection for potable water systems shall be in strict compliance with plumbing code and device listing requirements. Bypass arrangements shall not be permitted around backflow preventers.

## B.5 Hot Water Systems

### B.5.1 Hot Water Supply:

The following shall apply:

- Water heaters shall be semi instantaneous steam type with pneumatically actuated control valves, with temperature control accurate over entire flow range within plus or minus 2 degrees C (4 degrees F).
- Electric, oil, or gas-fired low volume storage tank type heaters may be employed only for special applications as approved by ORF, such as where steam is not otherwise available for the facility.
- Double wall heat exchangers shall be provided for potable systems, single wall is acceptable for lab/cagewash and nonpotable systems.
- Heaters shall be sized and arranged to provide N+1 redundancy for the total design load.
- Steam supply to heaters shall be sized for full demand plus 20% allowable for growth.

- Potential for legionella in potable water systems shall be considered and appropriately addressed based on facility risks and system application.
- Hot water shall be heated to 62˚C (144˚F) and tempered down to 51˚C (124˚F) or general distribution by master thermostatic mixing valves.
- Where shared water heaters are utilized to serve multiple systems or diverse functions (for example common water heaters serving for lab and potable), separate mixing valves or temperature control arrangements shall be utilized to permit the temperature of each system to be independently adjusted.
- Distribution shall provide 60˚C (140˚F) HW for kitchens, utility fixtures, undercounter dishwashers in breakrooms, and where otherwise required.
- Point-of use booster heaters at the kitchen dishwasher, cagewasher etc. shall be used where water temperature above 60˚C (140˚F) is required.
- Point of use instantaneous water heaters is not an acceptable substitution for connection to the hot water supply and return system.
- Distribution at 60˚C (140˚F) is acceptable for lab areas where required to serve equipment.
- Separate water heaters should be utilized for cagewasher applications, with 60˚C (140˚F) distribution.
- For large facilities with multiple pressure zones, hot water may be distributed at 60˚C (140˚F) and local master thermostatic mixing valves applied at each pressure zone to reduce to 51˚C (124˚F) prior to outlets.
- Copper-silver ionization shall be provided for potable hot water systems in clinical applications serving non-ambulatory patients, elderly, and those with compromised immune systems. Reduced temperature distribution at 46˚C (105˚F) may be utilized. Copper-silver systems shall not serve food service or pharmaceutical areas, and redundancy need not be provided for such treatment equipment, and monitoring protocol shall be developed.
- Hot water systems shall not use gaskets, seals or components constructed of natural rubber, which often serves as nutrient to bacteria.
- Hot water system shall be provided with pumped circulation and deadlegs shall be kept to a minimum.
- Large water storage tanks shall be avoided in potable systems.
- Valves and components shall be suitable for normal working temperature of 80-degrees C (176 degrees) at pressures of 1030 kPa, to allow for systems sanitization.
- Hot water outlet temperature shall be controlled by properly adjusted limit stops at point of use control faucets/mixing valves. Critical applications shall be provided with appropriately adjusted point of use thermostatic protection in accordance with Exhibit X8-3-C.

Exhibit X8-3-C Maximum Hot Water Outlet Temperature

| Fixture Type | Max Hot Water Outlet Temperature ˚C (˚F) |
|---|---|
| General sinks | 49 (120) |
| Cagewash Sinks | 60 (140) |
| Handwash sinks | 49 (120) [39 (102) for point of use generated tempered water] |
| Kitchen areas and sinks | 60 (140) |
| Lab Area Sinks | 49 (120) [60 (140) acceptable where 60 distribution required or requested] |
| Public Lavatory faucets | 43 (110) |
| Sensor actuated faucets | 39 (102) [Typical set point] |
| Showers | 43 (110) |

## B.5.2 Hot Water Circulation and Temperature Maintenance:

Hot water system temperature maintenance is required to ensure rapid availability of hot water at use points, and to minimize wasted water and energy. This shall be accomplished thorough the use of pumped (forced) circulation systems. The required circulation rate shall be calculated for each loop and sized to offset system heat losses. The A/E shall indicate the required flow rates for each circuit on the design drawings and calculate heat loss on the basis of system operating temperature, ambient temperature, and insulation value. For most interior building installations, the A/E shall use an 18°C (65°F) ambient temperature condition in sizing calculations for this system. A parallel hot water return shall be provided alongside (or near to) horizontal hot water supply mains and risers. Each hot water supply branch shall be circulated back to the hot water return and fitted with an appropriate balancing device with check valve as required to maintain hot water to fixtures within the recommended time criteria as outlined by ASPE, generally within 15 seconds. The A/E shall consider the effect of large diameter branch takeoffs from mains serving low-flow volume fixture outlets; and the outlet flow rate of the fixture when evaluating how close to the fixture the recirculation loop may terminate.

Serpentine-type hot water distribution, or the arrangement of hot water circulation in a single supply loop with the return taken only at the end as an extension of the horizontal of the fixture supply loop, is not allowed. By providing a parallel (whether adjacent or centrally located) hot water return, each supply branch may be circulated independently, and additions and renovations may effectively be connected to the common return without disrupting building function. Hot water return rate for each riser shall be carried by a balancing station at the top of the riser where the supply riser loops back to the return riser. In this way, the hot water return on each floor need only be sized for the flow rate required

to serve that floor, and the renovation of an area of the building is less likely to affect other areas.

The main hot water return from each floor shall be provided with a "floor balancing station," even where local circuits are individually balanced. A thermometer shall be included at the end of each floor's hot water return connection to the riser. Automatic balancing valves are generally not permitted due to inflexibility for future. Heat tracing is not permitted as a substitute for provision of central building hot water circulation.

Hot water return systems serving kitchens and cagewash areas shall be sized for a 3°C (5°F) temperature differential. General building areas shall be sized for a 4°C (7°F) maximum differential, except that higher differentials (up to 8°C (15°F) may be used where justified by the specific application. The A/E shall be cognizant of the pressure differential required for proper adjustment of balancing valves. A minimum flow of 0.06 l/s (0.0159gal/s) shall be provided with a 13 mm (1/2 in.) pipe size. Reduced size balancing valves applied to larger diameter returns may be provided where justified by the required flow rate and provided within acceptable velocity limitations.

Each vertical pressure zone shall be provided with its own circulation pump and heat loss recovery means specific to that pressure zone. The use of pressure reducing valves, orifice plates, balancing valves and other means shall not be permitted as a means to balance pressures for interconnection between zones.

*Legionella* provisions are not required with industrial/lab hot water systems. Hot water may be produced at 51°C (124°F) and directly distributed. In some cases, 60°C (140°F) distribution is desired to accommodate laboratory equipment or other operational requirements. Over-temperature shutdown protection is not required in industrial hot water systems. Master thermostatic mixing stations are not required, unless hot water is from a source above 62°C (145°F). Where a shared water heater is utilized to serve multiple systems, each system shall include its own thermostatic temperature control. Animal research facility cagewash equipment should be provided with independent water heaters, served from the industrial cold water system, softened if required.

## B.5.3 Hot Water System Over-Temperature Protection:

Protecting building occupants from dangers of scalding is of primary importance, however; as it becomes necessary to increase hot water production temperatures to facilitate use requirements or to minimize bacterial growth such as *Legionella*, the risk of scalding increases. Thermostatic mixing stations are the preferred method of temperature control prior to patient distribution and whenever serving shower or other sensitive applications.

Fail-safe over-temperature protection shall be provided downstream of master mixing valve stations that serve non-thermostatic type shower faucets or whenever providing hot water supply to non-ambulatory patient areas, anytime water is produced over 51°C (124°F). The over-temperature device shall consist of a temperature transducer, solenoid valve, and alarm signal to BAS. The over-temperature protection device shall be arranged to isolate a single mixing valve assembly and alarm an over-temperature condition. A minimum of two thermostatic, high-low systems shall be provided, each with its own over-temperature protection, and each capable of maintaining minimum 80% of the design peak flow at the design pressure drop so as to ensure continued supply of hot water in the event an over-temperature condition activates shutdown of a single mixing valve assembly. Each sensing probe, outlet check valve, and the piping design at the mixing valve station shall be properly arranged to prevent actuation of both valves in the event of failure of only one device. All mixing valve assemblies shall be properly sized to effect proper temperature control under conditions of minimum flow. The use of only a single high-low master thermostatic mixing assembly is acceptable for lab facilities, provided the supply temperature to the mixing valve is not over 60°C (140°F), a normally closed and locked maintenance bypass is provided at the mixing valve, and each shower on the system and any other critical temperature control application is served with local or point-of-use thermostatic (or combination thermostatic and pressure balance) protection listed in accordance with ASSE for the respective application.

Where separate booster heaters are utilized for system heat loss recovery, the A/E shall ensure adequate controls and fail-safe over temperature protection is provided as necessary to preclude risks of scalding.

### B.6 Mechanical Water:

Water used for makeup to mechanical systems shall be connected to either potable or non-potable water service with backflow protection (arranged in parallel if serving multiple equipment). Sizing shall be based on initial or quick-fill requirements and (where applicable), design flows for backup cooling conditions.

## 8-3-10 Design Guidance

### A. Available Water Supply:

The available water supply shall be analyzed on the basis of flow test data resultant of a proper hydrant flow test performed by DFM on the closest effective hydrant, performed in accordance with NFPA 291, during the design phase. All systems shall be designed a minimum of 10% below the water flow curve, but not less than a 35 kPa (5 psi) allowance for future demands on the supply main and to account for flow test accuracy. The A/E shall evaluate water supply source conditions at the time of flow test and make the appropriate

adjustment(s) in calculations as required to account for seasonal system capacity fluctuations and similar conditions. The adjustment for low hydraulic gradient (water level range of allowance in the supply tank relative to time of the flow test) or lowest operating pressure point shall be made prior to designing supply systems a minimum 10% below the available supply curve.

The A/E shall provide an on-site water supply quality analysis indicating key water quality parameters specific to the building site to determine need for any specialized water treatment, water softening, purified system, aquatic, and animal drinking water supply make-up conditions, and to identify any system material compatibility issues. For projects on the Bethesda Campus, this may be waived by the project officer for non-critical systems, where sufficient data exists for proper design.

Building-wide water softeners and treatment equipment is not typically required for NIH buildings in Bethesda and Poolesville, Maryland. Program requirements suggesting the use of such equipment shall be verified by the A/E in the early design stages. Water quality shall be determined for all other jurisdiction areas. An on-site water analysis to address all primary water parameters shall be performed by a qualified firm and submitted no later than 35% design documents. The results of the water supply analysis shall influence the need for water treatment, softening, production of purified water, and be utilized by the A/E to confirm general materials compatibility.

## B. Systems Sizing Guidance:

The following provides guidance for the design and sizing of NIH water systems:

- Industrial water system sizing is driven by user requirements, which are normally difficult to define. The design criteria for each type of space shall be established on a per program basis so that the utility services are delivered in sufficient quantity and pressure to meet current and future requirements. Design criteria shall be documented and approved early in the design stages.
- Emergency eyewash and emergency shower demand flow rate need not be added to the plumbing water demand for purposes of sizing the combined incoming water service when the incoming water service sizing includes all other plumbing and fire water demand.
- The A/E shall consider the unique demands and applications of plumbing systems at the NIH when sizing systems, especially when utilizing standard Hunter's Curve derived sizing methods and when determining fixture unit values. Because of the size, application, and equipment used in NIH facilities, the A/E shall thoroughly consider application of sizing methodologies to avoid drastic undersizing or oversizing of systems.

- The application of diversity factors for use in sizing any system should always be substantiated.
- The design demand of the largest, most demanding zone of lawn irrigation (or maximum flow of zones operating at one time) shall be included in the design calculations as plumbing demand. Likewise, any constant flow mechanical equipment or miscellaneous demands shall be included.

## C. Backflow Prevention Device Application Guidance:

Exhibit X-8-3C clarifies the level of protection required at points of use when fed from the NIH lab water system:

| Item | Required Device when fed from lab (isolated )water system |
|---|---|
| Faucets in lab, vivarium, and Cagewash | ASSE 1001 AVB (vacuum breaker) faucet spout |
| Fume Hoods | ASSE 1001 AVB mounted high on exterior face of hood |
| Hose Stations | ASSE 1011 HBVB, ASSE 1001/ ASSE 1056 AVB/SVB per listing, ASSE 1015 DCVA or ASSE 1024 Dual Check, or Approved integral device at hose station. |
| Laboratory Ice Machines | None required |
| Undercounter Glasswasher designed with integral backflow preventer or air gap | None required |
| Cage/Rack/Tunnel Washers | ASSE 1013 RPZ |
| Necropsy/Downdraft Sinks | ASSE 1001/ ASSE 1056 vacuum breakers or ASSE 1013 RPZ |
| Point of Use Water Purification | None required |
| Laboratory Autoclave | ASSE 1012 DCIAV or ASSE 1015 DCVA |
| Liquid Ring Lab Vacuum Pump | ASSE 1013 RPZ |
| Low hazard potential, non-toxic connections | None Required |
| Moderate hazard potential, non-toxic connections | ASSE 1012 DCIAV, ASSE 1015 DCVA, ASSE 1024 Dual Check |
| High hazard potential of toxic, pathogenic, or dangerous connections | Air Gap, ASSE 1013 RPZ, ASSE 1001/ ASSE 1056 per listing |

### D. Research Equipment Water:

Research equipment such as lasers, NMR equipment, mass spectrometers, etc., often require a water source for cooling and adequate drainage facilities. Where possible, such equipment shall be connected to the process-cooling water system and recirculated for re-use. Where equipment operating conditions, pressure requirements, temperature limitations, or backpressure restrictions require the use of a plumbing water source, either the industrial water system shall be used or potable water provided with an ASSE 1013 backflow preventer. Plumbing water systems may be used only as a backup for re-circulating systems. Equipment connections frequently require pressure-regulating valves, relief devices, balancing valves, flow controllers, and temperature regulators to complete their installation. Drainage connections shall be indirect and sometimes require gravity flow. Floor sinks shall be used to handle the large, intermittent discharges.

## 8-3-30 Design Document Requirements

The following additional design document requirements apply specifically to building water systems:

- Backflow Protection: The A/E shall specify that a log be provided to NIH at the conclusion of a project indicating the exact location, type of device, and service function for each backflow preventer that requires annual testing (any device provided with test cocks, such as double-check assemblies, reduced-pressure principal devices, pressure vacuum breakers, etc.) This log shall be included in project close-out documents.
- Hot Water Circulation: The A/E shall indicate the required flow rates for each hot water return circuit on the design drawings.

# Section 8-4: High Purity Water Systems



## 8-4-00 Design Requirements

### A. Systems Overview:

The quality of water distribution in a central building distribution system shall be established as a joint decision among the researchers, the A/E, and the Project Officer. The water quality decision shall reference an industry standard (such as ASTM or NCCLS) or be very specific as to the water requirements so that the system can be appropriately engineered and maintained.

Numerous types and combinations of water systems are installed for laboratory use, and specific applications may require use of distillation, deionization, and RO technologies. A central fully circulating reverse osmosis system to supply general use water with use of local polishing equipment at specific point-of-use areas is most commonly provided, typically as a medium grade (ASTM and NCCLS Reagent Grade Type III or Type II) system with enhanced parameters to limit bacterial colonization. Point of use polishing equipment is typically used in individual laboratories to achieve the required grade of high purity water for specific needs. Researchers typically do not have the confidence that the central system has a consistent high quality (or the right quality for individual research), so they ultimately install polishing equipment anyway.

Type III grade water as specified in ASTM Standard D 1193 shall be provided for heat exchangers used for steam humidification, electrically powered sterilizers, distillation unit, glassware washing, and central material service. The program of requirements shall confirm adequacy of proposed systems and determine additional systems and use areas for a specific project.

### B. Common Requirements:

A water supply analysis shall be prepared during the design stage to determine the degree of treatment required based on incoming supply and use demand conditions and to best select treatment equipment for the specific site and application

Water supplies for pharmaceutical or animal drinking water purposes shall be from completely independent, dedicated purification systems sourced directly from potable water.

Storage tanks serving purified water distribution systems shall be designed to provide a minimum of 24 hours operating capacity. Production equipment shall provide total required capacity in not over 8 hours of operation. Primary equipment downstream of the storage tank shall be arranged in parallel, to allow for continuous supply of purified water to research spaces. All systems are designed as circulating type with features to minimize bacterial colonization, regardless of required water quality. 254 nm UV light and submicron filters shall be provided for all systems. Additional UV light (such as 185 nm) is not typically required and should only be provided only as needed for TOC reduction, based on a more stringent required water quality parameter. The distribution system shall be designed to maintain the temperature of the water under 29°C (85°F). Where it is determined the system could be subject to infrequent use and temperature climb in excess of heat dissipation rates, the use of a sanitary heat exchanger and/or variable speed drive (VSD) controlled circulation pumps shall be considered to minimize purge waste. Drains receiving waste water from high purity water systems and production equipment shall be routed to the corrosion resistant laboratory waste piping system. RO water may discharge to the sanitary piping systems where required, however connection to corrosion resistant piping systems is preferable and required where deionization or stills are employed.

Purified water systems shall be of the constantly circulating type, designed such that a minimum velocity corresponding with a turbulence Reynolds Number (Re) of not less than 10,000 is achieved under all conditions, including peak design demand. Higher scouring velocities may be required in some applications, but typically 10,000 to 20,000 Re is adequate. The system shall be designed to provide a minimum use pressure of 140 kPa (20 psi) at outlets (after polishers), and maximum pressure shall not exceed 550 kPa (80 psi). Pressure requirements at polisher inlets shall be verified and is typically at least 240 kPa (35 psi). The A/E shall consider surge pressure ratings of the system components in determining necessary system zoning. Pressure reducing valves shall not be used in the distribution system as a substitute for multiple distribution zone pumps, with the exception that pressure control devices shall be provided at the end of supply or end of return as required to maintain adequate pressure under varying demand conditions. Where possible, production systems should be located at the top of the system to minimize pressure on system components.

The A/E shall clearly define sizing parameters of the systems including total daily consumption, peak system flow, hourly system flow, distribution flow to each floor or zone, and maximum flow per outlet. Pure water systems normally have a large diversity between

low- and high-flow conditions with multiple peaks sometimes occurring throughout the day. Each floor or zone shall be balanced in the field to provide a predetermined quantity of water so that all research functions are satisfied. As with other NIH primary systems, the system production equipment and distribution mains shall be designed to incorporate a 20% overage for future demands or load compression.

Dead-legs in distribution and return piping (for typical systems) shall be minimized to 6 pipe diameters in length where possible, however sanitary diaphragm valves are not required in Type III water systems, and absolute zero deadleg requirements are typically only necessary with water systems providing high grade (such as Type I ) criteria.. All branches shall be circulated. A rotameter and sanitary diaphragm-type valve shall be provided in the return line from each laboratory floor to permit proper balancing and visual indication of flow. The piping system distribution on each floor shall be independent of other floors to the connection with the main supply and return riser. Appropriate sampling and sanitation ports shall be provided. Circulation pumps shall be constructed of Type 316 stainless steel and should be arranged to provide operational redundancy.

Provision of circulated taps with valving in the normally open position shall be incorporated to allow for future connection points when anticipating pure water system expansion for the future. Cutting into existing pure water system risers and the use of valves with dead-legs capped for the future is discouraged because of the potential for contamination of the system.

For Type I and other critical systems, a single contractor shall provide the entire system, including piping and outlets, so that there is a single point of responsibility for the successful operation.

Where serpentine distribution systems are utilized from one laboratory into another, they shall be arranged such that the supply and return system serves only a single floor and only a single laboratory wing prior to connecting to the main supply and return risers. For large facilities, the system shall be further segregated to facilitate shutdown of services by corridor or groups of laboratories, as necessary to minimize potential disruption during future modifications. Direct return arrangements consisting of a parallel supply and return main with a branch takeoff from the supply and return main to serve each laboratory shall be considered to allow for individual shut-down, reduced branch pipe sizing, and maximize future flexibility. Where recirculating faucets are required, direct return arrangements shall be utilized to provide a connection point for return water flow. Each connection to the return main shall be provided with a balancing valve or engineered flow restrictor and appropriate flow meter. All distribution systems shall be sloped to permit full drainage of system contents.

ASSE 1013 backflow protection shall be provided at the point of make-up water connection with the potable water supply system.

Pipe materials and sizing shall be consistent with the defined system parameters and shall be compatible with the degree of water purity required. Piping, valves, fittings, and fabrication techniques shall be selected on the basis of the ability of each item to handle pure water without inducing contamination. Pipe sizes shall limit excessive velocity and pressure drop while preventing low flow or stagnant conditions in the distribution. Dead-legs shall be avoided where possible, and floor branches shall be circulated.

Where projects involve renovation work, new materials shall be identical to existing and shall be installed in a similar manner, and connections to existing systems shall require prior NIH approval. The A/E shall arrange piping so that a minimum number of connections to existing systems are required, and in such manner as to preclude introducing contaminants.

Where extensive expansion is anticipated, higher supply to demand ratios and higher turbulence values may prove beneficial. It is important that the A/E receive a signed-off system schematic and design criteria document for the pure water system before the design is completed. Design parameters may change during the construction phase as equipment technology evolves and final equipment selections are made. The water system designs, to the extent practical, shall consider future requirements, pressure and flow changes, and water quality improvements.

## 8-4-10 Design Guidance

### A. Reverse Osmosis:

Reverse osmosis is normally utilized for primary treatment with deionization or distillation for secondary treatment, as required for point of use water parameters. RO systems consist of a series of built-up components, which typically includes the following:

- Thermostatic Temperature Control Makeup Supply to 25°C (77°F)
- Backflow Protection
- Automatic back-washable multimedia filters.
- Automatic Alternating Water Softeners
- Automatic back-washable carbon filters.
- Duplex 25 micron and 1 micron prefilters.
- Reverse osmosis unit.
- Storage tanks with spray ball and submicron air filtration
- Tank controls and filters.

- Duplex circulation pumps.
- Polishing service deionization tanks with blending capability. (Only where required).
- Resistivity, purge, flush, pressure, and temperature monitoring equipment for production and distribution control and protection.
- Ultraviolet sterilizer (typically 254nm) and light trap.
- Duplex Post-filtration
- Alarm system and PLC

## B. Deionized Water Systems:

Deionized water is used for experiments and washing laboratory glassware and equipment. A central deionized water system is not typically used to supply deionized water throughout a laboratory building but may be required to supply water to a central washing facility. Small deionizing equipment is utilized locally for individual laboratory requirements. The requirement for a central washing system and local laboratory systems shall be established on a per program basis.

A means for measuring and totalizing flow from the exchange units and to measure the resistivity of the deionized water shall be provided. Regeneration systems shall be evaluated for central systems. Deionized water shall be circulated through a return piping system and filtered to maintain high purity. The A/E shall provide NIH with construction drawings, specifications, cost data, supplier list, and system requirements.

## C. Distilled Water Systems:

Distilled water may be obtained from a central distilled water system or from a still located within the laboratory. Typically, point-of-use stills are preferred. Steam is utilized in production for central distilled water systems; electricity is used for small local systems. For central systems, titanium distilling equipment, and polytetrafluoroethylene (PTFE) or titanium-lined storage tanks shall be sized to ensure an adequate daily volume of water. Multiple stills and tanks shall be utilized to allow downtime for maintenance purposes. Still size shall be determined on the basis of 24 hour operation of the stills and the provision of adequate storage tank capacity. Local stills shall be made of glass. Distilled water may be deionized and degassed where ultra-pure water is required. Piping, fittings, and the wetted parts of valves shall be made of high purity, virgin resin perfluoroalkloxy PFA or PTFE, typically Schedule 40.

Stills shall be installed in nearby mechanical rooms to minimize the piping distribution of distilled water and shall be placed at an elevation within the building to enable gravity flow to the outlets in the piping system. Mechanically pressurized systems are not recommended, since the pump and fittings may introduce impurities in high-quality water. Distilled water

systems shall not be cross-connected with any other water system such as deionized, RO, or local water-polishing systems.

### D. WFI and Pharmaceutical Water Systems:

WFI water shall comply with the most current USP Guide, shall be FDA validated, and shall be produced by multi-effect still and distributed at a maintained temperature not less than 80°C (176°F) through a fully validated system designed by a process engineer with specialized experience in validated pharmaceutical WFI and pure steam systems engineering. WFI piping shall be 316L high purity 15 Ra electropolished stainless steel with autogenous orbital welds, and tanks shall include a clean nitrogen blanket with 0.2 micron PTFE heat-sterilized filters. WFI and USP water shall be sourced directly from potable water supply and shall be completely independent of laboratory or other process purified water systems. Where heat exchangers are utilized, the system shall be designed such that the WFI or USP water is always at a higher pressure than the process fluid.

## 8-4-30 Design Document Requirements

Full P&ID documents are required for Type 1 water systems and WFI systems (which shall include all steps for validation).

Strict specifications and quality control are critical to ensuring contaminant free piping systems and preclude leaks, including detailed quality control requirements for specialized welded plastic (fusion) joint systems.

# Section 8-5: Animal Drinking Water Systems



## 8-5-00 Design Requirements

The type of Animal Drinking Water (ADW) system (whether automatic or manual) and required water quality and pressures shall be determined through consultation with the program veterinarian and use group. On-site water analysis shall be performed to analyze the need and type of treatment. Where building water systems are softened, the need to remove excess sodium shall be considered. The need for cross contamination control provisions (such as between transgenic spaces), varying species, and research areas shall be considered and appropriate provisions provided as approved by the user group.

The ADW production and distribution system shall be completely separate from any other water system, including laboratory purified water distribution. ADW shall be supplied directly from the potable water system with makeup water backflow preventers, followed by any required treatment. Storage tanks, circulating pumps, flush valves, pressure control stations and controllers, as well as appropriate monitoring provisions shall be provided to isolate each system from risk of cross contamination during normal operation and system sanitation procedures. The maximum temperature of the system shall be controlled and monitored. The entire system shall be operated only in such manner as appropriate to the drinking water needs of the animals served. The system shall be designed to provide continuous ADW to the vivarium, and shall be automatically monitored to ensure a continuously available drinking water supply. Individual flush valves should be provided for each room or rack, the supply system should not serpentine from one room to the next.

Many NIH animal facilities use a combination of bottle, packet, and automatic watering systems. Accommodation for automatic watering at a future time or in a portion of the facility shall be considered. The A/E shall investigate the applicability of specialized water processing for the facility (i.e., RO, ultraviolet [UV] sterilized, chemical injection, acidification, etc.), as well as special zoning requirements with the use group. In addition, the impact of specialized water on the proposed bottle fillers, proportioners, and distribution piping shall be

considered. The use of plastic mounting clips for piping should be avoided. Where automatic systems are utilized, a manifold flushing station is required in the cage wash area.

## 8-5-30 Design Document Requirements

Design documents by the A/E shall either provide full system design drawings or an adequate schematic representation of the system (showing key distribution elements, zones, and major component locations) to be followed with full system vendor design drawings that shall be submitted for NIH review prior to procurement.

# Section 8-6: Drainage Systems



## 8-6-00 Design Requirements

### A. Description:

Waste, and vent systems shall meet the requirements of reference plumbing codes. Each plumbing fixture or drain shall be trapped and vented in accordance with code requirements. Vent systems serving plumbing systems are of the conventional through-the-roof type, consisting of dedicated waste and parallel vent stacks. Mechanical vent devices, air admittance valves, stack aerator and de-aerator systems, single stack, and other non-conventional systems are not utilized. The sizing and pitch of drainage piping shall be per code and the requirements described in this section. Piping, materials, and joint methods shall comply with Exhibit X6-3-A. Piping Materials in the HVAC Section. A sanitary DWV system shall be provided to serve conventional sanitary plumbing fixtures, bedding disposal, and contaminated condensate wastes. A second corrosion resistant waste and vent system shall be provided to serve laboratory research areas, aggressive waste discharges, cage wash areas and associated floor drainage and equipment (with the exception of bedding and solid waste disposal). A third, segregated grease waste system is required for commercial food service areas.

Exhibit X8-6-A Minimum Waste Piping Diameters

| Pipe Type | Minimum diameter mm (in.) |
|---|---|
| Vent Pipe | 32 (1-1/4) |
| Buried Waste and Vent Pipe | 50 (2) |
| Waste Pipe Penetrating a Single Floor (located downstream of trap arms) | 50 (2) |
| Waste & Vent Stacks through Multiple Floors | 75 (3) |

Drains receiving high-purity water discharge, such as laboratory sinks adjacent to water polishers, and drains at dialysis and pure water production equipment, as well as condensate from fuel-burning appliances and other potentially corrosive wastes shall discharge to the lab waste system utilizing corrosion-resistant materials. Such drain systems shall empty in neutralization systems prior to their discharge into the public sewer. The neutralization system shall be adequate to provide the proper pH discharge in accordance with sewage authority discharge regulations. For approved piping material see Exhibit X6-3-A. Piping Materials in the HVAC Chapter. Drain and vent piping serving oil interceptors and similar combustible systems shall be approved metallic materials only. While pH treatment shall not be automatically provided for all facilities, the A/E shall consider the discharge regulations of WSSC from the entire NIH campus and the need to protect the longevity of NIH private sewer collection mains and lateral infrastructure. At a minimum, pH monitors and sampling points are required for all lab and vivaria facilities.

The effluent from NIH buildings shall meet WSSC code requirements and shall comply with the requirements of the Environmental Management/Radiation Safety, Section 1-9 of the DRM. In general, effluent with the following basic characteristics shall be excluded from the sanitary sewer system:

- Any liquid or vapor having a temperature higher than 60°C (140°F).
- Any water or waste containing grease or oil or other substance that solidifies or becomes viscous at temperatures between 0°C (32°F) and 60°C (140°F).
- Any wastes having a pH lower than 5.5 or higher than 9.0, or having any other corrosive property capable of causing damage or hazard to structures, equipment, or personnel, interceptors, other sewage-handling and transporting facilities, or other treatment works.
- Unmetered water such as air-conditioning condensate, stormwater, ground water, etc. except as allowed per the code.
- Radioactive wastes, viable pathogenic wastes, flammable or explosive liquids or other wastes in violation of EPA requirements and NIH permits.

The public and private onsite sanitary sewer systems shall be protected against the potential discharge of grease and oil originating from food-handling, parking garages, transformer vaults, etc. Requirements for interceptors are further discussed in Section 1, Environmental and Radiation Safety.

# B. General Drainage System Design Considerations

## B.1 Size, Slope, and General Arrangement:

Waste systems shall be designed to maintain a minimum velocity of 0.6 m/s (2 fps), and 0.9 m/s (3 fps) where possible. Special attention is given to the design of sanitary waste systems serving low-consumption water closets as well as systems transporting wastes that increase potential for pipeline stoppages. Systems shall be hydraulically designed to minimize potential for stoppages and backflow of wastes or suds and to ensure provisions for maintenance. Horizontal waste branches shall be sloped at not less than 2% and often require slopes in the range of 3%, to aid in solid waste transport. Excessive slopes beyond 5% and less than 45° are not permitted. Slopes of 1% and less shall not be allowed in piping sizes 150 mm (6 in.) and smaller. While certain minimum pipe sizes are required by NIH, the A/E shall consider the negative effects caused by significant oversizing or undersizing horizontal waste piping systems, especially building drains and sewers. Adequate load must be provided to ensure sufficient flow depth for waste transport. The use of 125 mm (5 in.) diameter piping is acceptable and should be encouraged where adequate for the design load. Drains and traps serving floor drains, floor sinks, and janitor service sinks shall not be less than 75 mm (3 in.) diameter, regardless of anticipated usage. Individual showers and tubs shall be provided with 50 mm (2 in.) diameter traps and waste. Floor drains and floor sinks in kitchens shall be provided with drains and traps, which are at least 75 mm (3 in.) diameter, except that 100 mm (4 in.) diameter outlets shall be used for the grease waste system. The use of horizontal waste piping less than 50 mm (2 in.) shall be limited to trap arms serving lavatories, drinking fountains and similar fixtures. The A/E should arrange fixture connections to provide “trail flows” to enhance drain line carry, especially when dealing with fixtures that discharge solids or slurry.

## B.2 Distribution:

Waste and vent stack locations and horizontal distribution of piping shall be independent for each building wing to minimize potential disruption during future renovations. With the exception of stacked major toilet rooms, vertical waste and vent stacks that transverse multiple stories shall not be placed directly behind fixtures, but rather in dedicated permanent utility shafts and appropriate building columns. The A/E shall consider the potential for any one floor to be renovated in the future without causing excessive disruption on adjacent floors or necessitating future vertical stack offsets. The A/E shall avoid routing piping in ceilings above or slabs below major electrical or data communications equipment areas. In as much as possible, piping shall not be buried below major mechanical or infrastructure equipment, or below major laboratory or vivaria equipment items. Waste piping should not be buried in slabs under animal holding rooms except as necessary, and shall not be buried under electrical rooms, transformer vaults, surgical, chemical, biological,

or rad waste storage areas. Piping shall not be located above panel boards or switches, including the required service areas for this equipment. The A/E shall consider potential disruption, which could result if the need to access lines for repair or renovation were to be required. Drains receiving cold condensate shall be properly insulated.

Vertical stacks and vents shall be located at permanent chases and at building columns rather than in partitions. Every attempt shall be made to design stacks in a straight vertical configuration and to utilize offsets of not greater than 45° from vertical where possible. Waste and vent piping stacks that transverse multiple floors of the building shall not be located in interior partitions. Branch connections into main waste stacks shall be made with wye fittings installed as low in the ceiling space as possible, and branch connections into main vent stacks shall be made with inverted wye fittings installed as high as possible, providing maximum flexibility for directional changes and elevation requirements for future connections while minimizing potential need to shut-down and disrupt major system stacks.

The routing of waste piping above food service areas, vivariums, surgery areas, and similar areas shall be avoided. However, where installation is unavoidable, specific safeguards shall be provided to maintain sanitation for these areas. The use of fixtures with waste discharge above the floor is recommended, as well as the use of double-contained waste piping where indicated in Exhibit X6-3-A. Piping Materials in the HVAC Chapter. Drain pans, heavy-duty couplings, and similar items shall not be considered equivalent to the safety provided by a leak-tight double-contained waste system over critical areas. Sanitary drainage systems above grade (non-buried) shall be provided with appropriate thrust restraint, joint rodding, and bracing in accordance with the recommendations of the CISPI handbook. Special bracing provisions are generally required for cast iron piping 125 mm (5 in.) and larger. All waste piping and receptors subject to condensation due to cold wastes shall be insulated.

Dedicated branch lines serving food service areas shall connect to the building drain independently of other areas of the building, reducing potential waste stoppages in main lines to back up into sanitary kitchen areas. Independent grease waste systems shall be provided as described in this section, under “Grease Waste”.

Vent systems shall slope upwards toward the roof terminal, and dry vents shall not offset horizontally less than 150 mm (6 in.) above the flood level rim of the highest fixture served. Connections between vent pipes and a vent stack shall be made at least 150 mm (6 in.) above the highest fixture on the floor connected to the system, but not less than 970 mm (38 in.) above the floor. Vent terminals shall not be located within 7.6 m (25 ft) of any air intake or window, or in such proximity to any building opening or occupied area to be infiltrated by sewer gas or vapors. Vents shall be adequately separated from sources of

positive or negative pressure, fans, etc. to maintain atmospheric pressure within the venting system. Interceptors shall be provided with vents to prevent air locking and may require an independent local vent, laboratory waste, or sanitary vent, based on the application and design.

## B.3 Cleanouts:

The provision of adequate cleanouts is merely providing access for clearing stoppages and does not supersede a thoughtful system design to minimize stoppages. Opening of cleanouts serving plugged waste lines, as well as the cleaning operation itself, often results in unsanitary conditions caused by splattering and spillage of waste. The following design requirements shall apply to the arrangement of cleanouts:

- Two-way directional cleanouts shall be provided at the building exterior, arranged to provide effective clearing of mains through a separate entry for rodding upstream or downstream of flow. Upstream piping layout should be selected to permit drain cleaning cables inserted in the exterior two way cleanout to extend upstream to the maximum extent possible prior to dead-heading.
- Two-way cleanouts may be used in other areas where beneficial due to access restrictions.
- Two-way cleanouts shall not be provided in lieu of cleanouts at the upstream end of horizontal mains, but rather as a supplement to enhance the system.
- Wherever possible, horizontal piping in ceilings shall be served by a wall cleanout located in a bathroom or similar readily washable area on the floor above that discharges to the horizontal main, rather than requiring opening of cleanouts in ceilings.
- Cleanouts shall be provided as required by code, including at the base of waste stacks, and to serve upstream ends of horizontal drains and fixture branches. Fixture branches less than 3 m (10 ft) long that are connected to a main served by a cleanout do not require separate cleanouts unless necessary due to heavy solids or grease.
- Cleanouts are not required or desired at each directional change, but shall be located such that no more than a maximum aggregate change of direction of 135° occurs prior to use of a cleanout.
- The maximum distance between cleanouts, including the length of cleanout risers shall not exceed 30 m (100 ft).
- The removal of a fixture such as water closet or urinal shall not be considered equivalent to provision of adequate cleanouts.
- Full-size cleanouts shall be provided for all waste lines up to 150 mm (6 in.) in diameter, and not less than 150 mm (6 in.) diameter for sizes above 150 mm (6 in.).
- Cleanouts are required for all waste systems at all floors, whether above or underground.

- Wall cleanouts shall be specified with appropriate plugs. Tapping of plugs directly into the waste or vent stack is not permitted.
- Each floor cleanout cover shall be stamped to indicate the system served per Exhibit X8-6-B.

### Exhibit X8-6-B Cleanout Cover Stamp Designation

| Floor Cleanout Cover Type | Stamp Designation |
|---|---|
| Laboratory Waste | LW |
| Sanitary waste | SAN |
| Storm drainage | SD or STORM |
| Grease waste | GW |

## B.4 Potential High-Temperature Wastes:

Cagewashers, autoclaves, steam humidifiers, and similar equipment shall be specified with suitable aftercoolers to ensure discharge waste temperature does not exceed maximum system temperature restrictions, typically 60°C (140°F). Pipe materials serving autoclaves, cagewashers, and other potentially high temperature waste shall be only as approved for high temperature waste systems, with appropriate design to address expansion/ contraction issues (even where equipment includes the on-board aftercooler). The high temperature waste line shall be extended at least to the point of adequate cooling through mixing with sufficient flow from other fixtures, or to a point where sufficient heat dissipation occurs such that calculated temperature under after cooler failure conditions would be below the 60°C (140°F) limit. This typically includes the serving waste stack, to at least the point of connection with the building drain or main. Normal autoclave waste is not corrosive and may be routed to either the sanitary or the laboratory waste system. Where equipment includes a high-purity water rinse, discharge shall be to the laboratory waste system to accommodate the corrosive nature of high-purity water. The A/E shall specify floor sink and floor drain outlet connection methods that are compatible with the selected waste piping material and system application. .Connections between floor sinks and floor drains and the selected piping material shall be specified in consideration of the potential for expansion and contraction when receiving high temperature wastes. Some piping materials (such as high-silicon iron), are not of iron-pipe-size external diameter and will require special connections to drains and floor sinks. Where serving high temperature discharge, a flanged mechanical joint adapter with a PTFE flange gasket connecting to a flanged stainless steel floor sink outlet is often the most appropriate way to address material transitions subject to thermal cycling. Threaded connections with stainless steel nipples are also acceptable. Boiler blow down wastes shall be appropriately cooled through blowdown tanks, aftercoolers, or similar means in accordance with code.

## B.5 Gravity Drainage and Backflow of Waste:

Drainage systems shall be designed to flow by gravity, wherever possible. The use of pumping systems shall be avoided. Where pumped systems are required, equipment is of the duplex type, each capable of discharging 100% of the incoming peak flow in the event of a pump failure. Building areas that are sufficiently elevated above the sewer to not require discharge through a pumping system shall be routed independently to discharge by gravity.

The A/E shall arrange plumbing systems to prevent sewage backflow into the building due to a stoppage in the exterior sewer by providing relief outside the building through sewer manhole covers. Backwater valves shall be provided outside the building for any drainage main that serves fixtures or equipment whose flood level rim is not at least 230 mm (9 in.) above the elevation of the exterior manhole cover serving the system, or above the next upstream manhole. Drains with flood level rim elevations higher than the above reference point shall not be combined with lower level mains upstream of the backwater valve. The backwater valve shall be located at the connection with the manhole, or with similar accessible means, to permit access for sewer rodding, or other service. Sufficient venting shall be provided to serve the building sewer either through stacks that do not discharge through the backwater valve or by provision of a relief vent. The use of individual backwater valves at fixtures is not permitted. Where possible, the use of backwater valves that are full-way, normally open type (or devices located at the manhole) are preferred as they are less susceptible to damage or problems related to cable drain cleaning operations. Fixtures with flood level rims that are located below the crown level of the sewer shall be pumped.

## B.6 Indirect Waste:

Indirect waste connections shall be provided for all plumbing fixtures/equipment that is of public health concern, as well as for equipment drainage as required. Food preparation, dishwashing, and warewashing equipment, autoclaves, ice machines, and similar equipment shall discharge with an appropriate air gap to an approved indirect waste receptor. An air break may be utilized for items such as photo equipment and non-potable equipment discharge, where an indirect connection is required, but a full air gap is not needed to protect sterility.

Indirect receptors shall be stainless steel floor sinks with appropriate capacity, and with the proper part grate design to eliminate splashing. An internal dome strainer or sediment bucket shall be provided. Cast-iron floor sinks may be provided in mechanical rooms and similar unfinished areas. Floor drains with funnel tops may be used for limited flow applications, such as from ice machines. Stainless steel wall outlet boxes connected to a 50 mm (2 in.) diameter concealed standpipe may be used for various equipment drainage,

provided the box is not concealed or inside casework. Floor drains and floor sinks shall be installed with their top grate flush to 3 mm (1/8 in.) below the finished floor, with the finished floor slightly tapered to drain toward the receptor. The installation of floor sinks with rims installed above the floor is not permitted. The only time waste receptors shall be installed with rims above the floor is where specifically necessary to preclude floor drainage from entering the system, such as where a receptor is installed to direct clear water waste to the storm system, or in limited cases where a standpipe receptor/ hub drain is permitted. Indirect waste shall not terminate at other plumbing fixtures, including janitor mop sinks, but rather to the appropriate waste receptor. While indirect waste from laboratory equipment sometimes drips into laboratory sinks, indirect waste shall never terminate over culinary plumbing fixtures or similar applications where use or sanitation is impinged in any manner.

The use of hub drains and standpipe receptors is not allowed in finished areas because of the potential for trash and debris to enter the drainage system, as well as their unsanitary nature. The interior of these devices is not readily cleanable, and projections above the floor present both sanitation and safety hazards. Such devices, however, may be appropriate in certain mechanical room applications receiving clean wastes, as well as when connected to wall waste outlet boxes. In no case shall any standpipe receptor be less than 50 mm (2 in.) in diameter. Standpipe length shall be limited per code.

Indirect waste receptors shall be installed in readily accessible, normally occupied spaces and shall not be located in toilet rooms, crawl spaces, casework, closets, or any concealed spaces. The one exception is that floor sinks may be located in dedicated walk-in utility connection areas adjacent to sterilizers and similar equipment where such configuration is consistent with the normal equipment installation. In locating floor sinks and other indirect waste receptors, the A/E considers the potential for a waste line stoppage to result in overflow, and ensures the location permits cleanup, constant visual monitoring, and is not likely to cause damage to the building, sanitation issues, or hazard to occupants. The placement of indirect waste receptors shall permit removal and cleaning of the sediment bucket or dome strainer and cleaning and mechanical rodding of the device in the event of a stoppage. Special care should be applied in locating floors sinks and drains in pits serving lab equipment to ensure accessibility. Indirect waste receptors shall be located in the same room as the fixture served, and to minimize the length of indirect waste piping. Waste receptors shall be of sufficient depth shall be selected to prevent splashing and accommodate peak discharge conditions. Undercounter glasswashers and similar equipment should terminate to adjacent sink wye-branch tailpieces where possible, or may terminate to an accessible unconcealed wall outlet box, or if necessary a funnel top drain or if needed a floor sink. Food waste disposers, bedding disposal, and similar equipment shall not be permitted to discharge through indirect waste receptors, but rather shall be directly connected to the sanitary drainage system. As with other drainage systems, the A/E shall

be careful to specify floor sink and floor drain outlet connections that are compatible with the selected waste piping material. Floor sinks and floor drains shall be installed to be readily visible, with at least ½ of the grate exposed and removable. Floor sinks and floor drains may be fully concealed below equipment only where equipment is readily mobile and elevated over the drain top at least 100 mm (4 in.).

The use of gravity indirect waste lines (including food service and air handling condensate piping) less than 25 mm (1 in.) in diameter shall be avoided, as smaller lines have proven difficult to maintain due to stoppages. Plumbing connections to laboratory, vendor designed, and food service equipment shall be included in plumbing documents after coordination with the respective vendor/ consultant. The A/E shall carefully evaluate vendor and specialty consultant drawings and actual equipment installation requirements to provide proper systems in conformance with the DRM, and shall not rely on directions of vendors alone or specialty consultants alone to ensure a code-compliant, well-designed system.

## C. Laboratory Waste:

### C.1 Description:

Laboratory waste or other special waste and vent systems shall be separate from the general use sanitary system and shall be provided in accordance with the general drainage design considerations for waste systems above. This section provides additional system-specific requirements. The A/E shall carefully evaluate sizing of laboratory waste systems. Many items of equipment do not directly correspond to flow rates and values of common Hunter's Curve fixture unit tables, as the tables are based around flow discharge characteristics of domestic plumbing fixtures and water closets. Cage and tunnel washers and similar equipment can generate particularly high peak flows and often produce suds-laden wastes. Diligence shall be provided to validate system sizing for proper operation and for consideration of waste stack arrangement, segregation of wastes, and appropriate relief venting and suds control design to prevent backflow.

### C.2 Distribution:

In existing buildings, it is often necessary to route waste piping horizontally in walls during renovations to minimize disruption to floors below. The need for adequate cleanouts and sufficient pipe slope is especially important in such cases to minimize stoppages and facilitate maintenance.

The A/E shall specify mechanical joint traps under laboratory sinks and fume hoods. The need for bottle traps in lieu of P-traps at fixtures shall be established on a per program basis

through consultation with ORF. Borosilicate glass piping is not permitted for direct connections to darkrooms or for vent penetrations through the roof.

## C.3 pH Monitoring and Neutralization:

pH treatment systems are not automatically required at all laboratories, however automatic monitoring systems (as a minimum) are required for all lab and vivaria buildings. The A/E shall discuss the need for pH treatment systems with NIH based on the specific facility, though practice is generally to install pH treatment systems for most lab and vivaria facilities to protect campus infrastructure and ensure compliance with regulations. Additional requirements can be found in Chapter 1 of the DRM, Environmental Management and Radiation Safety.

Where pH adjustment systems are utilized, the A/E shall consider the characteristics of effluent to be treated. In general, pH treatment systems shall be of the active type, capable of positively neutralizing acidic or caustic pH to acceptable parameters in consideration of varied inflow rates and pH levels, through use of automatic injection and mixing of acid and base reagents (typically sulfuric acid and sodium hydroxide), monitored and controlled by a PLC. pH treatment systems shall be fully accessible, and shall not be located in rooms housing air handler units or mechanical air intakes. The A/E shall consider segregation of pH treatment equipment and chemicals in a dedicated, properly ventilated service area, and shall ensure provisions for removal and replacement of equipment. Treatment systems relying on limestone or marble chips are ineffective for alkaline waste streams and not suitable for wastes containing solids or slurry, including cagewash areas and main building lab waste systems. The cleaning and disposal of trapped solids and media is subject to strict disposal guidelines, requires extensive maintenance, and as such any application of limestone/marble chip systems shall be carefully evaluated and is generally allowed only for temporary conditions or very limited application with ORF approval.

The A/E shall evaluate whether a batch-type, or continuous flow-through, system is most desirable. Waste streams with significant solid matter load is better suited to the batch-type process, however in either case the selected system shall be specially designed to automatically handle the anticipated solid load and flush all solids without requiring extensive operator maintenance, strainers, or exposure to the waste stream. Laboratory waste treatment systems shall be sized to the system demand and consider the facility load profile.

Most laboratory waste streams are effectively treated in a very short time utilizing continuous flow/hybrid systems, and excessive retention times are typically not required when using properly designed equipment. The A/E should be cognizant of these issues,

and system application to prevent drastic over-sizing. Where high quantities of deionzied water is discharged to pH treatment, it may be beneficial to incorporate sodium bicarbonate injection and influent equalization to stabilize the influent waste stream. All systems shall be designed to allow continuous operation during service. The A/E shall specify quality pH monitors and components, and pH monitors, pumps, and similar controls shall not be located inside the tank. Systems shall utilize sufficiently sophisticated controls to match reagent injection to the influent requirements and influent and effluent characteristics. Continuous, flow-through systems shall include controls and tank designs to permit limited retention in the event of a spike in the pH of the influent stream. Batch-type systems shall default to continuous flow-through mode in the event a batch tank is removed for service. Dual mixers should be provided for reliability. System discharge valve and controls shall be on standby power to ensure continuous drainage and prevent flooding.

Treatment systems shall be designed to automatically compensate and minimize normal solids accumulation to minimize maintenance requirements by including features such as solids handling circulation pumps, sloping bottoms with low point circulation drainage into the circulation loop, and in the case of batch tanks, conical bottoms. Systems shall be provided with on-board day tanks automatically filled from separate reagent drums. The A/E shall carefully consider the required location for the pH treatment system such that multiple systems need not be provided for most buildings, and to ensure that only the very lowest floors of the building that cannot drain by gravity even without pH treatment would need to be pumped into the system. Upper levels should flow by gravity into the system, with only the lowest level pumped into the system as required, with treated effluent discharging by gravity. The A/E shall consider the location of the treatment system in relation to required chemical delivery, maintenance, and facility operations, and may find it necessary to use remote chemical tanks and transfer piping (which shall be double contained and monitored), to reach the treatment system location. The A/E shall coordinate utility requirements for peak and normal flow rates of pH treatment systems with the site infrastructure.

Unless parallel systems are provided (which is normally undesirable), a normally closed bypass discharging through a pH monitor/recorder shall be provided, and the system shall be arranged for gravity drainage through this manually opened and normally locked/monitored bypass in the event of system failure or maintenance. The pH monitor, whether stand-alone or part of the treatment system, shall incorporate an electronic record for not less than 30 days of waste stream characteristics, and shall alert a general fault or contravention to the building automation system. The pH probe must be capable of servicing and calibration without disrupting building waste flow. Containment/ diking requirements shall be provided in accordance with code, and shall include reagent storage as well as day tanks. Where pH treatment systems are not required, pH monitors may be installed in the following configurations:

- In a special recessed channel in the serving manhole or access pit outside the building, so as to lay horizontally constantly wetted, without impeding the flow stream. The A/E shall coordinate between disciplines (plumbing/civil) as required for the proper fabrication of this manhole to hold the pH monitor probe effectively without flow obstruction. Manufactured bracket assembly for this purpose, removable and replaceable without entering manhole, and amplified signal to an interior control panel. Such arrangements are readily available from manufacturers of process waste water equipment and controls.
- In-line on the main lab waste leaving the building, installed in a flow-through sampling basin with normally closed locked bypass. Any sampling basin or trap for this purpose must be arranged to be self-cleaning, with special care for systems subject to solids or slurry loading. A service access pit should be provided for full access.
- For extramural projects not owned or primarily operated by NIH, manual grab sampling from pH sampling manholes may be used in lieu of automatic monitoring, where approved by the local AHJ. In such cases, the corrosion resistant lab waste piping system shall extend to the sampling manhole before any change to site utility piping materials.

### C.4 Photo Processing Equipment:

Photoprocessing equipment shall be provided with an approved silver recovery device adjacent to the equipment with discharge connected to the lab waste system. Waste neutralization tanks shall be provided adjacent to the equipment, regardless of whether a central laboratory waste neutralization system is available.

## D. Vivarium Waste

Animal research facility waste shall be separated from general use sanitary systems and lab waste from other areas, and shall comply with the general waste system requirements above. Solid waste from jetted drains at holding rooms shall discharge to the sanitary waste system (or ideally to the sanitary sewer manhole) independently of other building areas through corrosion resistant piping, and shall bypass pH treatment systems unless pH treatment is specifically required based on program requirements and designed to automatically accommodate solids. Other areas free of solids may route to the building lab waste system. Waste piping systems shall be adequately sized and designed to accommodate large quantities of liquid waste and solids leaving the animal facility, particularly from animal rooms and cagewash areas. Floor or trench drains with automatically flushed jetted traps or in-floor flushing blow-out water closets shall be

provided in large-animal (NHP and Kennel) rooms. Drains and in-floor water closets shall be funnel or round-bottomed, with no flat horizontal surfaces to accumulate waste. 19 mm (3/4 in.) rinse lines should be provided at the beginning of the sloped troughs or trench drains in each room, though for small applications and with prior approval of vivaria staff, manual hose washing stations may be used for this purpose. Most small-animal holding rooms do not require a drain or hose bib. The location of the troughs should be carefully coordinated with cage rack requirements to ensure free movement of racks. A percentage of holding rooms in the facility may be designed with a drain to accommodate fish tanks, rodent swim tanks, or farm animals. Farm animal drainage systems typically require special consideration to preclude stoppages, such as use of large diameter piping, slopes, and engineered flushing systems, and may require special consultation with ORF for approval.

Cagewash area discharge shall route through the lab waste system with corrosion resistant piping, with careful attention to waste sizing requirements due to surge flows, suds, and high temperature discharge.

Design precautions for the effective disposal of solid waste in the form of bedding, paper, feces, animal carcasses, and other miscellaneous wastes shall be considered. Bedding shall be disposed of by a mechanical slurry system at the Dirty Cagewash area, piped directly to the sanitary main, independent of other building areas. Bedding disposal units shall connect to minimum 100 mm (4 in.) traps, hard piped with a cleanout on the trap inlet, and ideally the main should receive the discharge of at least one non-chemical sterilizer or similar high flow non-corrosive water waste fixture, as well as be provided with a slope of not less than 2%, and 3 to 4% where possible with minimal horizontal offsets.

### E. Oil Based Waste

Oil interceptors shall be provided to serve potential sources of oil discharge (including transformer vaults), and shall be engineered to provide effluent discharge levels of solvent extractable matter of mineral or synthetic origin to a maximum of 10 ppm and total suspended solids to a maximum of 350 ppm. In some cases, the use of coalescing filters may be required (depending on application) to ensure clean discharge in accordance with most current environmental discharge regulations.

## 8-6-10 Design Guidance

Waste piping systems shall be designed and installed in a direct manner, with minimal horizontal offsets, to aid in the efficient transport of wastes. Piping mains located above ceilings shall be parallel to the building construction and shall not transverse building spaces diago-

nally. Long-radius fittings shall be specified for horizontal-to-horizontal and vertical-to-horizontal direction changes. Double wyes shall not be used in the horizontal position for drainage. Sanitary tee fittings shall not be installed on their side or on their back as a waste fitting, or to serve as a connection of a vent to a waste pipe because of the potential for stoppage. Sanitary crosses shall be avoided in drainage systems. Specially manufactured double-fixture fittings shall be specified for back-to-back or side-by-side fixtures discharging to the same vertical waste. The A/E shall specify that piping be installed in proper alignment, with attention to joint quality, square cutting of piping, and proper insertion of piping into fitting sockets. Connections of individually vented fixture branches to horizontal mains shall be through rolling offsets at a 45° position above the horizontal centerline, to minimize disruption to waste and air flows and minimize negative effects on solids transport. Such connection methods shall be noted on drawings or in specifications.

When utilizing horizontal wet vents, circuit vents, combination waste and vents, or other specialized venting methods to serve drain inlets, the arrangement shall be taken as a separate branch off of the main waste line to serve the circuit or wet-vented portion. The main itself shall not serve as the horizontal wet vent, as this limits flexibility for future renovations by potentially disrupting proper function of the vented branch if the main requires extension to serve other areas and future loads.

Condensate drain lines shall slope a minimum of 20 mm/m (2%) and shall be a minimum 25mm (1 in.) in size. Cleanouts shall be installed at each 1.6 rad change in direction. Trap seals shall equal air-handling unit static pressure at the trap plus a minimum of 50 mm (2 in.). Clear water, non-contaminated atmospheric condensate shall discharge to the storm system. Chemically contaminated condensate (such as steam humidifier waste) shall discharge is indirect waste to sanitary. AHU condensate lines shall be sized according to Exhibit X8-6-C.

### Exhibit X8-6-C Condensate Line Sizing

| Pipe Size mm (in.) | Maximum Cooling Load in W (ton) |
|---|---|
| 25 (1) | Up to 17,050 (5) |
| 32 (1-1/4) | Up to 102,300 (30) |
| 40 (1-1/2) | Up to 170,500 (50) |
| 50 (2) | Up to 511,500 (150) |
| Run multiple condensate lines | Above 511,500 (150) |

## 8-6-30 Design Document Requirements

The A/E shall carefully specify backfill and excavation methods for the underground system layout and installation to prevent loss of piping slope or alignment. The quality of the underground installation often sets precedence for the durability and maintenance requirements of the system, and piping installed at minimal slopes often fails due to improper bedding and backfill.

All portions of drainage and vent systems downstream of fixture traps shall be tested for not less than 4 hours, with a 3.0 m (10 ft) water head prior to concealment. Air testing is not utilized on plastic piping systems. Final testing after setting of fixture traps shall ensure traps are both watertight and gastight to 25.4 mm (1 in.) water column. A water manometer test, peppermint test, or approved equivalent method shall be specified, typically as a water manometer inserted through the trap of a water closet or other fixture after all fixtures are set and traps filled with water. With the building drain and vent stacks plugged, the test pressure shall hold for 15 minutes without loss. Upon test completion, removal of all vent stack plugs shall be verified.

# Section 8-7: Building Storm Drainage Systems



## 8-7-00 Design Requirements

### A. Description:

A separate drainage system shall be provided for stormwater from roof areas and to receive non-contaminated clear water atmospheric condensate. The building storm drain shall extend outside the building and connect to the campus storm sewer system. Storm drainage systems shall be conventional atmospheric pressure gravity drainage type that does not rely on storage of water on the roof, special drain weirs, or non-conventional system components. Any required storm water retention shall occur outside and downstream of the building in such a manner as to not allow water accumulation on the structure.

The number and sizes of drains shall be adequate to convey stormwater from areas being drained at the same rate as water is collected in those areas. At least two drainage points shall be established for each roof or areaway drainage area, and no roof drain shall have a drain outlet smaller than 75 mm (3 in.) diameter. Roof and deck areas 46 square meters (500 square feet) and smaller may be provided with a single drain, provided overflow or other approved relief provisions are incorporated to prevent build-up of water in the event of failure of the primary drain.

A dedicated secondary emergency roof drainage overflow system shall be provided to serve flat roof areas, except where such roof areas are provided with appropriately sized overflow scuppers. The overflow drain system shall consist of overflow drains installed alongside each roof drain, with a weir 50 mm (2 in.) to 75 mm (3 in.) above the roof low point. The system shall be piped independently to discharge through downspout nozzles spilling to the exterior, approximately 300 mm (12 in.) above grade. A stainless steel rain cap shall be specified over the top of the overflow roof drain dome grate to prevent intrusion of rainfall during normal conditions.

## B. Sizing Criteria:

Either the primary storm drainage or secondary overflow drainage/ scupper system shall be sized based on the 10 year, 5-minute storm, which for the Bethesda campus corresponds to a rainfall rate of 180 mm/hr (7 in/hr). The remaining system may be sized based on the 100-year, 60 minute storm [which for the Bethesda Campus corresponds to a rainfall rate of 85 mm/hr (3.4 in/hr)] or 10-year, 5 minute storm at the A/E option. The clear water waste loads from air handling unit and other approved non-roof drainage discharging to the storm system shall be based on the peak load, and sizing for 20% overage of the total clear water waste load shall be included in the system design. Sizing of both primary and secondary systems shall incorporate horizontal roof surfaces as well as an allowance for adjacent vertical areas that may drain onto the roof structure where applicable.

- In cases of a single vertical wall adjacent to a lower roof, an allowance of 50% of the vertical area above the roof shall be included in the design load for the lower roof area.
- In cases of two opposite walls of equal height, no additional vertical area shall be added.
- In cases of two adjacent walls, 35% of the total wall areas above the lower roof shall be included in the design load.
- Where adjacent walls are of differing heights, similar appropriate allowances shall be included in the design.
- In limited cases where any overflow drain from a higher roof area is permitted to spill to a lower roof, both the primary and secondary drainage for the lower roof shall be sized for the load of both roof areas. This practice is generally undesirable, and shall not be utilized for primary drainage.

Building storm drain slopes shall provide a minimum velocity of 0.9 m/s (3 fps) to keep sediment and debris in suspension, however 1% slope will be permitted for above ground lines 75 mm (3 in.) and larger and where required to meet sewer inverts. Underground storm sewers outside the building shall be sized to include a 20% future allowance for expansion.

## C. Distribution

Storm drainage leaders (including overflow drains) shall be located in permanent shafts or at building columns. Vertical piping shall be routed as straight as practical, with minimal offsets. An expansion joint or acceptable horizontal offset (swing joint) shall be provided at connections to each roof and overflow drain. Drain leaders shall not be located in interior partitions. The system design shall avoid placement of horizontal piping above conference spaces, offices, electrical rooms, or other critical areas. Lower roof areas shall not be connected to rainwater leaders within 600 mm (24 in.) of a horizontal offset, and then only with wye-type fittings. Fittings specified for directional changes and branches in storm

drainage systems shall be of the same long-radius type required for use in sanitary systems. The entire storm and overflow drainage system, (including vertical piping and drain bodies) shall be insulated. Wherever possible, cleanout requirements for horizontal piping in ceilings should be served by accessible roof and area drain inlets provided cleanout or access point spacing does not exceed 30 m (100 ft) or 135-degrees aggregate directional change, and the roof area can be safely accessed with drain cleaning equipment, without necessity of hoisting. Roof and overflow drains shall include sump receivers, under-deck clamps, and aluminum or cast iron domes.

Standpipes and clearwater waste receptors shall not connect to the storm drain system in locations as to be subject to backflow from storm water surges. Backwater valves on standpipe drains shall not substitute for adequately sized piping systems with branch lines connected to wye-branches into rainwater leaders away from horizontal offsets and surge zones.

Adequately sized area drainage with outlets not less than 75 mm (3 in.) diameter shall be provided for exterior walk ways, stairs, and as otherwise necessary to prevent accumulation of water. Area drains should generally be sized to relieve peak rainfall with a maximum 7 mm (1/4 in.) head. Area drainage in area ways and otherwise subject to blockage shall be provided with dome tops. Area drainage in areas provided with pavers shall be arranged to discharge both surface drainage and accumulated flow below the paver through use of specially designed promenade-type perforated drains. The grate of all area drains shall be sufficient for the anticipated traffic loading.

## D. Underslab/Subsoil Drains:

Underslab sub-soil drainage piping shall be provided for slab on grade and buried structure where recommended by the geotechnical or structural consultant. The underslab/ subsoil drain system shall be designed and spaced as per the geotechnical engineer recommendations, using not less than 100 mm (4 in.) diameter perforated laterals and 100 mm (4 in.) or 150 mm (6 in.) mains as required, with filter fabric and a positive slope 5 mm/m (typically 0.5%). Where a sump pump is required for subsoil drainage, it should be located at the building exterior where possible and shall consist of two pumps sized for N+1 redundancy, on standby power. Areaway drains, rain leaders, downspouts, or other aboveground drainage points shall not be connected to subsoil drains. An exterior sand trap or catch basin shall be provided where subsoil drains connect to the storm drainage system. In addition, where subsoil drains connect to the storm drainage system without the use of pumps and is subject to backwater backflow, an automatic backwater valve shall be provided at the sand trap to prevent reverse flow of stormwater into the subsoil drains. The backwater valve shall be provided at the inlet of the subsoil drain to the sand trap to permit

access to the device. The cover of all interceptors shall be appropriately stamped to identify the interceptor type and system served. Whenever stormwater vents are required (such as for sealed sumps), they shall be piped independently of any sanitary vents.

### E. Gravity Drainage (Storm) and Backflow of Waste:

Refer to Section 8-6 Drainage Systems. Building areas, which are sufficiently elevated above the storm drains, do not require discharge through a pumping system and shall be routed independently to discharge by gravity.

Plumbing systems shall be arranged so that a stoppage in the exterior storm sewer shall not result in stormwater backflow into stairwell area drains, subgrade parking areas, or similar low-level stormwater inlets that are not fully exterior of the building. Stormwater shall be relieved outside the building through manhole covers, catch basins, or other exterior storm-drainage inlets.

Where such drains are located less than 230 mm (9 in.) above the elevation of the stormwater relief point, automatic backwater valves shall be provided. Roof drains and other drains with flood level rim elevations above the reference point shall not discharge through the backwater valve. Drain openings with flood level rims that are not located above the crown level of the storm sewer shall be pumped. Pump systems serving subsoil/underslab drainage, critical applications, or any application serving more than one drain or multiple areas shall be provided with not less than two pumps for N+1 redundancy, and shall be on building standby power. Pump system shall be municipal duty grade, and capable of passing not less than 13 mm (1/2 in.) solids.

## 8-7-10 Design Guidance

### A. System Application:

Only clear-water, non-contaminated atmospheric drainage suitable for direct discharge into natural waterways shall be connected to the storm drainage system. Water such as clean atmospheric condensate from air-handler/ fan coil units is acceptable, however discharge of chemically treated, contaminated, and chlorinated potable water, as well as high temperature water violates provisions of the Clean Water Act, and shall be directed to sanitary. Discharge of unmetered storm water into the sanitary system is prohibited by WSSC and unnecessarily burdens sewage treatment systems.

The waste discharge chart in Exhibit X8-7-A shall be used to determine where various services are piped.

## Exhibit X8-7-A Waste Discharge

| Type of Discharge | Storm Drain Discharge | Sanitary Drain Discharge |
|---|---|---|
| Air conditioners: water cooled, non-contaminated | X | X |
| Area well | X | |
| Bearing cooling water: reclaimed water on individual determination based on contamination | X | X |
| Bearing cooling water: reclaimed water if chemically treated | | X |
| Boiler blow-down basin | | X |
| Floor drains | | X |
| Condensation drains: AHU, cooler coil, refrigerated equipment (Atmospherically generated, non-contaminated condensate) | X | |
| Cooling tower: if treated, type of treatment chromates | | X |
| Cooling water: industrial noncontact | X | X |
| Dies, tools, etc.: water cooled | | X |
| Drinking fountain | | X |
| Elevator Pit Drain, Hydraulic fitted with oil-precluding pump system | | X |
| Elevator pit drain: except hydraulically operated elevators | | X |
| Fire system blow-down: automatic, if no neutralizing additives are applied | | X |
| Food display case: refrigerated | | X |
| Grass areas | X | |
| Humidifiers, non-treated water, non-steam: | X | X |
| Humidifiers, treated steam or water: | | X |
| Ice machine drain: commercial, and industrial | | X |
| Ice chest drain: ice cube | | X |
| Loading docks: enclosed | | X |

| Type of Discharge | Storm Drain Discharge | Sanitary Drain Discharge |
|---|---|---|
| Overflow from ponds: ornamental, utility; check for chemical treatment (if any contamination must route to san). Ozone treated with no other chemicals may be permitted to storm with prior approval. | X | X |
| Overflow from tanks and reservoirs: industrial process, if treated | | X |
| Parking Garage, Top Deck Exposed to Rainfall | X | |
| Parking Garage, Intermediate Decks | | X |
| Potable (chlorinated) Water Waste | | X |
| Roof drainage | X | |
| Subsoil drainage | X | |
| Water-softener backwash: commercial, industrial, and residential | | X |
| Welding equipment: water cooled | | X |

*Note: This table may be used for discharge requirements for storm and sanitary waste. Design shall include air gaps as necessary to prevent cross-connection between sanitary/storm systems and the water/air system.*

Air Handler Unit Drainage: Non-contaminated atmospheric condensate shall discharge to storm as clear water waste, and be fitted with a normally closed bypass arrangement with a valved connection and threaded cap near the AHU to permit extension of a hose to a sanitary drain during coil cleaning operations. The clean condensate drains for large AHU's shall discharge through an adequately sized insulated standpipe that is not less than 75 mm (3 in.) diameter and of sufficient length to preclude overflow, that passes through a sleeve (with water stop) embedded in the slab, projecting at least 50 mm (2 in.) above the slab and located near the AHU drain to preclude tripping hazards. Galvanized steel or copper condensate drain line shall extend down into the standpipe approximately 50 mm (2 in.) (as an airbreak), and be fitted with not less than a 50 mm (2 in.) top access cleanout to permit the standpipe to be cleared, and the above noted bypass valve arrangement. Near to the AHU, a sanitary floor drain shall also be provided, with floors sloped and sealed near the floor drain area to receive ancillary moisture. Drainage for steam humidification shall be separately collected, and if discharging to the building drainage system, shall waste only through the sanitary system with an aftercooler, and discharging either through a standpipe receptor

or floor sink. Special care shall be provided for the installation of any floor drains, standpipes, and floor sinks to preclude leakage around the drain perimeter to the floor below.

An independent garage drainage system shall be provided for parking garage drains below the top parking deck that is not directly exposed to rainfall. Garage drains shall be of the dry-pan type (connected without traps), have not less than 100 mm (4 in.) diameter outlets, and include a sediment bucket and ANSI special load class ductile iron secured grate and anchor flange. Except for the top deck exposed to rainfall, the garage drains shall collect to a common 150 mm (6 in.) collector line that discharges to an oil/sand separator designed to ensure discharge does not exceed 100 ppm oil. The interceptor shall incorporate a 150 mm (6 in.) deep submerged water trap seal at the inlet, and a 450 mm (18 in.) deep submerged seal on the outlet, as well as a dedicated vapor vent direct to the exterior terminating at least 2.1 m (7.0 ft) above the highest parking deck and away from any air intake or building opening. The provision of dry pan drains eliminates requirements for freeze protection of traps and prevents accumulation of oil or flammable liquids in trap seals. An adequately sized automatic electrically actuated trap seal primer shall be provided to ensure continued maintenance of the interceptor trap seal. Garage drains shall be located at low points adjacent to ramp turnabout and at sufficient intervals to permit garage floor washdown and preclude puddling. Backwater valves shall be provided where necessary to protect parking garages where potential for flooding exists due to the elevation of the drains in relation to other points of relief, and where otherwise necessary to protect mechanical and electrical rooms that may be located in the garage from backflow of storm or sanitary sewers. Interceptors shall be provided with internal ladders and non-slip rungs. The top deck of the parking garage exposed to rainfall shall be directed to the storm drainage system independent of the storm main serving occupied buildings. The requirements for an oil/sand interceptor to serve the top deck drainage shall be determined based on the most current state and county requirements (currently Montgomery County requires an oil interceptor prior to release to the water way), and is typically necessary unless otherwise handled downstream prior to release to waterways or retention basins. Trench drains shall be provided at parking garage ramp entrances and exits as required to prevent water buildup. Heel-proof drains shall be provided at any stair landing exposed directly to rainfall from sides or above, and shall have outlets not less than 75 mm (3 in.) diameter. Adequate washdown shall be provided (typically 38 mm (1-1/2 in.) outlets), drainable from a single point at the base of the system, with backflow protection, insulation with metal jacket, and heat tracing.

## 8-7-30 Design Document Requirements

Storm and overflow drainage systems above grade (non-buried) shall be provided with appropriate thrust restraint, joint rodding, and bracing in accordance with the recommendations of the CISPI handbook. Special bracing provisions are generally required for piping 125 mm (5 in.) and larger.

The entire storm drainage systems (except foundation and under-slab subsoil drains) shall be tested for not less than 4 hours with a 3.0 m (10 ft) water head, or 60 minutes with 35 kPa (5 psi) air.

# Section 8-8: Compressed-Gas Systems



## 8-8-00 Design Requirements

### A. Description:

Gas systems may consist of a cylinder or bulk supply system, each with a separate reserve supply. The reserve supply shall operate automatically to supply the pipeline if the primary supply becomes exhausted and shall consist of a minimum 3 days' average consumption unless the local resupply situation dictates a greater secondary supply capacity. Primary supply should typically provide not less than two weeks consumption for local systems, and at least 3 weeks consumption for bulk systems, after including the 20% overage. Point-of-use gas cylinder systems are sized in accordance with program requirements through consultation with the use group. Compressors are utilized for production of compressed air, except that cylinders may be utilized for very limited applications where provision of central compressed air would be impractical and is approved by the NIH Project Officer. Bulk supply systems shall include a telemetry system that is compatible with the various vendor suppliers as utilized by NIH.

Laboratory and vivarium gas supply and distribution systems shall be completely independent of gas systems serving clinical patients. Gas system components for medical or vivarium, or laboratory use shall, at a minimum be factory cleaned and packaged as for oxygen service. Prior to operation, all gas systems shall be verified free of cross connections, pressure tested to at least 150% design operating pressure using inert gas of cleanliness and purity not less than the design process fluid, and verified of required cleanliness and purity throughout the entire system.

The arrangement of reserve cylinder or back-up supply connections shall be made to preclude discharge of reserve cylinders during normal operation or loss of gas due to failure of the bulk tank or primary supply (such as a bulk tank relief valve malfunction).

### B. Distribution:

Primary services to each floor of a building wing shall be connected to respective supply risers, independent of other floors or building wings. Risers shall be located either inside the

building wing served, or in a common area to multiple building wings. In general and unless noted otherwise, maximum velocity in distribution systems shall not exceed 20 m/s (4000 fpm), and pressure drop shall not exceed 10% for systems operating above 380 kPa (55 psi), and shall not exceed 20 kPa (3 psi) for systems operating below 380 kPa (55 psi).

An adequate number of valves shall be provided so as to facilitate maintenance; and to isolate systems for renovations and unexpected emergencies without affecting operation of adjacent spaces. Valves shall be provided at the base of each riser, at each riser connection, at branch piping to each laboratory equipment group, and at equipment requiring maintenance. Each distribution loop or double-fed main and risers shall be provided with sectionalizing valves such that a branch or portion of the piping serving an individual lab and individual floors may be shutdown without disrupting the service to the entire floor, other floors or building areas. Where valves are located above ceilings, thorough coordination of piping services shall be required to ensure proper access for valve operation.

Pressurized gases shall not be piped into a biosafety cabinet. The use of compressed gasses (such as lab air) has been shown to disturb intended airflow patterns within biosafety cabinets. Fuel gas has also proven hazardous, and is generally not required or desired in bio-safety cabinets following modern research techniques. The program shall consult with the NIH DOHS during planning for assistance and alternatives. Where fuel gas is permitted, an accessible emergency shut-off valve shall be provided immediately adjacent to the bio-safety cabinet.

NIH requires most pressurized gasses (with the exception of fuel gas, vacuum, and general instrument air) to be provided utilizing special materials and brazing methods to maintain system cleanliness, at least equivalent to that required for oxygen service. The A/E shall specify the performance qualifications to maintain system cleanliness. Brazing criteria of general lab gasses shall meet Section IX, ASME Boiler and Pressure Vessel Code or ANSI/AWS B2.2 Standard for Brazing Procedure & Performance Qualifications, both as modified by NFPA-99 or the Copper Development Association for medical gas application. Where high purity gases are required, additional specification criteria shall be provided to ensure product standards, joint quality and cleanliness consistent with the required application.

Stubouts for lab gas turrets shall be secured to structure to provide rigidity and the A/E should provide a stainless steel plate for wall-mounted turrets to protect walls from damage.

## C. Bulk Gas Systems:

Where sufficient demand exists, central bulk gas systems (including cryogenic tanks and vaporizers) shall be provided in lieu of numerous compressed gas cylinders. Typically, this applies to gasses such as carbon dioxide and nitrogen, but may vary for each project. Bulk systems shall be located in a secured area and in full compliance with NFPA standards. The specific location of bulk tanks shall be subject to NIH approval. For cases where a set contract is in place, the NIH project officer can advise as to the gas purveyor is to be utilized for provision and service of the bulk cryogenic tank farm, as well as how systems are to be specified for purchase or (less common) rental. Duplex vaporizers, refrigeration units, etc. should generally be provided as necessary to ensure continuous service. Stand-off warning signage shall be provided for bulk tanks with regards to safety valve/rupture disc discharge. Cryogenic piping systems shall be vacuum jacketed.

## D. Compressed Air Systems

### D.1 Compressed Air Production (Nonmedical Use):

Air for building processes are produced at the central plant and distributed to each building. This air is delivered to buildings at a pressure of 650 kPa (95 psi) to 830 kPa (120 psi) and is distributed throughout the facility at the delivered central plant air pressure, considered nominal 690 kPa (100 psi). The incoming plant air service shall be sized to supply 100% of the compressed air peak demand including a 20% capacity allowance for future expansion. For new buildings, a dedicated compressed air production system shall be installed as a backup to the central system and shall be capable of supplying 100% of the system peak demand with the plant air system completely out of service. Air from the campus central plant shall intertie into the building system upstream of dryers and filtration, and an arrangement of pressure transmitter and normally closed automatic control valves shall automatically activate the backup system upon pressure loss or drop below 590 kPa (85 psi). Air intakes shall be taken from the exterior of the facility, above the roof or at least 6.0 meters above grade, away from loading docks, generator exhaust etc., and at least 7.6 m (25 ft) from any powered exhaust or likely source of contamination.

Equipment capacity splits shall be selected to appropriately match the demand profile of the building to minimize waste of compressed air, including the selection of a duplex, triplex, or quadraplex arrangement of smaller compressors, rather than a single large or duplex unit. The system shall be set to automatically supplement the incoming plant air supply via a normally closed valve, actuated by a pressure switch. All compressors shall include an automatic exerciser such that each compressor is activated not less than once per week. Local control systems with system operating status and alarm condition readout shall be provided at the equipment. A remote signal-to-building automation system shall be limited

to a general fault alarm for each system source. The need for standby power shall be evaluated on an individual program basis, but is not typically required for general lab air systems.

If the plant air is utilized as a backup supply to the building compressed air system rather than as the primary supply, the building compressed air system shall be designed to maintain peak capacity by itself with any one compressor out of service. The incoming plant air supply is connected to the building system upstream of duplex desiccant dryers and high-performance coalescing filtration equipment. In this manner, the building distribution system and delivered air quality are protected from any contamination that might occur during distribution from the central plant to the building, such as in the event of a break in a line, construction debris, or mechanical failure.

Central compressed air serving laboratory and building control systems shall be oil-free, no oil permitted in the compression chamber of production compressors, and then filtered to remove hydrocarbons and particulates, and dried to a maximum pressure dew point of -12°C (10°F) through dryers capable of producing air down to -20°C (-4°F). In some cases, air will need to be dried to -40°C/F, and the need for widespread air at this level should be verified on a per-program basis before specifying dryers. While -12°C (10°F) is generally adequate for normal lab use, in no case shall the provided dewpoint be higher than 2.8°C (5°F) below the lowest temperature at which any portion of the system distribution will be exposed at any time of year. Where higher quality air is only sporadically required; additional dehumidification and filtering shall be provided at the necessary points of use rather than centrally. All dryers, filters, regulators and components shall provide N+1 redundancy to allow continuous service. Desiccant dryers may be pressure swing (heatless regeneration) type, utilize heat of compression, or be externally heated, however internal bed dryers are not permitted. Lab air shall be oil free and provided with duplex filtration (arranged in parallel) such that each filter passes the full design flow rate at a maximum pressure drop not to exceed 21 kPa (3 psi) as follows:

- Prefilters shall provide minimum of 98% efficiency at 3 micron.
- High performance coalescing filters shall provide .03 micron absolute
- Final particulate filters (after dryers) shall provide absolute filtration to 1 micron.

The A/E shall coordinate heat loads of compressor equipment with adequate ventilation and cooling of compressors. The use of liquid-cooled compressors supplied by the central process cooling water closed loop system shall be considered.

A primary "wet" receiver shall be installed immediately downstream of the compressor aftercoolers and moisture separator, but prior to the primary air treatment. This receiver shall be utilized to provide preliminary moisture removal, additional cooling, and to help minimize short cycling of compressors and reduce load on dryers and filters. After the desiccant dryers and final filtration, a "dry" receiver shall be provided for the required system stored energy. A final pressure control station shall be provided downstream of the receiver to stabilize distribution pressures. Receivers shall be provided with internal corrosion resistant coatings.

Control air systems shall provide air of quality that is in no case less than the requirements of the Quality Standard for Instrument Air, typically Class 2 or Class 3, as published by the Instrument Society of America. In some cases, -20°C (-4°F) air may be required for certain HVAC control applications, and final requirements including particulate and oil content shall be coordinated with the system. Process air serving door operators and similar devices are not required to be oil-free or clean for oxygen service, and should meet typical ISA standards for instrument air.

In the case of control air systems, the system shall be arranged to provide N+1 redundancy and preclude single point failure of air production equipment. Reliability can be accommodated by use of a dedicated control air compressor that is intertied with the supply from the primary control air or building air system, or through use of dedicated adequately sized receiver arrangement provided with inlet check valves or other means to ensure air for control system operations.

## D.2 Compressed Air Distribution (Nonmedical Use):

Risers for compressed air systems shall be provided as high pressure [nominal 690 kPa (100 psi) pressure systems], so that laboratories may utilize either high-pressure or low-pressure distribution via local pressure-reducing valves at the riser take-offs for each floor to deliver the necessary local or zone low pressure condition. Even where high pressure air is not initially required, valved and capped provisions shall be provided at the distribution space or riser take off for each floor, with forethought in system sizing to permit future connections. High-pressure distribution piping systems shall be sized to limit pressure drop to 10% of the system operating pressure. Downstream of the PRV's, 275 kPa (40 psi) laboratory air is distributed to turrets and is sized to limit pressure drop to 21 kPa (3 psi) at design demands to the farthest outlet. Velocities shall not exceed 1220 m/min (4000 ft/min). Conventional lab turrets shall provide a flow of 0.5 L/s (1 cfm) at every outlet station. High pressure air is sized based on projected demand requirements, and detailed programming. Special attention should be applied to sizing of systems with regards to quantity and type of high purity gas generators, air tables, and similar equipment which may have high con-

sumption rates and not allow significant application of diversity. Laboratory building diversity factors may be used for outlets if these can be properly assessed, and is typically provided for sizing of typical gas turrets.

## E. Carbon Dioxide Lab Gas:

Carbon dioxide may be required in some facilities as a central system. This requirement shall be verified with users on a per project basis. The A/E shall consult with program requirements to determine demand loading and door opening allowance for incubators, (typical baseline should be to allow for at least 3 door openings per incubator per day). A liquid carbon dioxide storage tank, vaporizer, and associated controls shall be located outside the building, sized such that bulk system refill is not required more frequently then every three weeks. Manifold cylinder systems (for smaller or local applications) shall incorporate not less than 2-week demand and 3 day reserve. Carbon dioxide system distribution pressure shall be at 175 kPa (25 psi), and maximum pressure drop at peak demand shall not exceed 21 kPa (3 psi). For facilities with limited carbon dioxide requirements, the system may be fed from manifolded cylinders located in a central area or building cylinder closets. Central carbon dioxide systems shall have redundant components and reserve backup to ensure uninterrupted supply to incubators. Redundant risers/ double fed mains should typically be provided to preclude single point failure, reference Functional Design Considerations. Carbon dioxide manifold rooms shall include oxygen level monitoring alarms.

## F. Liquid and Gaseous Nitrogen Lab Service:

Nitrogen may be required in some lab facilities as a central system and shall be verified with users on a per project basis. Where large demands are required, a bulk liquid nitrogen storage tank, vaporizer, and associated controls shall be located outside the building. Liquid nitrogen piping shall be of the static or dynamic vacuum jacketed type, and the location of freezer farm areas should be coordinated with bulk tank placement to minimize LN2 piping. For facilities with limited gaseous nitrogen requirements, the system may be supplied from manifolded cylinders located in a central area or building cylinder closets. Systems shall be designed to provide an uninterrupted gas supply. Medical gaseous nitrogen distribution systems are separate and independent of laboratory distribution systems, and are typically provided to operating rooms with control panels outside each individual operating room and an available pressure of 1240 kPa (180 psi). Nitrogen holding rooms shall include oxygen level monitoring alarms. Dewar fill station locations are generally outside the building (typically near the loading dock) and the specific location shall be coordinated with NIH DOHS for safety requirements and the NIH project officer. The location of dewar stations shall take due consideration of the safety and transport issues in transporting dewars to and from use points. Dewar fill stations shall be fully automatic type.

## G. Special Laboratory Gases (Cylinder Gases):

Research at the NIH has requirements for many different specialty gases, including helium, argon, hydrogen, oxygen, nitrogen, carbon dioxide, carbogen, and numerous gas mixtures of various purity. Planning shall allow for the proper storage of full and empty gas cylinders, including separate storage areas for flammable and oxidizing gases. Cylinder restraints shall be provided in storage areas and local distribution closets and at points of use in the laboratories. Cylinder restraints shall be secured to the building structure, toggle bolts and similar designs are not acceptable. Gas systems shall be designed in accordance with NFPA standards and fire codes, including provision of special gas storage cabinets, flame arrestors, and ventilation. The arrangement of specialty gas systems shall be coordinated with NIH ORF, DOHS, and DFM. Ultra-high purity gasses are typically located near to the point of use, and special system materials and procedures will be required to maintain system cleanliness and gas purity.

## H. Medical Gas Systems

### H.1 Medical Gas Production:

Medical gas systems shall comply with the latest edition of NFPA Standard 99. Bulk systems over 566,335 L (20,000 scf) shall comply with the latest edition of NFPA Standard 50. Services for animals shall be completely independent of medical gas systems (including separate source supply tanks). All medical gas and vivaria systems and alarms shall be served by the emergency power system.

A separate compressed-air system independent of the laboratory compressed air system shall be provided and shall contain oil-free air compressors, desiccant air dryers, air filters, and line pressure controls. Air compressors and equipment shall be not less than duplex configuration and shall be in full accordance with the current edition of NFPA 99. Only desiccant-type dryers shall be utilized for medical air systems. MA systems shall be equipped with a duplex purification package capable of removing particulates 0.01 micron and larger. 100% redundancy of this equipment shall be provided.

MA compressors shall take their source of air from filtered outside atmosphere (or air already filtered for use in operating room ventilating systems). Air shall not contain contaminants in the form of particulate matter, odors, or other gases. MA systems shall have continuous dew point monitors, CO monitors, duplex air dryers, redundant controls, and duplex storage tanks. The MA system pressure shall be 345 kPa (50 psi) at the most remote outlet. Except for very limited demands and with prior NIH project officer approval,

medical air shall be produced by central, dedicated medical air compressors in conformance with the latest edition of NFPA-99.

Where oxygen is required to serve animal research facility spaces, it shall be provided from a separate system than that of the medical oxygen for patient use. Systems are designed to maintain pressure at the use point between 345 (50) and 380 kPa (55 psi). Oxygen systems are sized to limit pressure drop across the system to not exceed 21 kPa (3 psi). No oxygen branch or outlet connection line may be less than 13 mm (1/2 in.). The minimum size of any main or riser shall be 19 mm (3/4 in.). Secondary emergency oxygen reserve supply for medical (human) use shall be provided to serve the facility and shall be connected to a point in the system remote from the primary supply bulk tank with appropriate emergency valving to ensure that a break or disruption in the underground main oxygen supply piping or bulk tank supply malfunction does not result in disruption of oxygen to the facility.

Nitrous oxide shall be supplied by a piped central system at a terminal unit pressure of 345 kPa (50 psi) in all operating, cystoscopy, cardiac catheterization, and angiography rooms, and other locations as required by program. Nitrous oxide gas manifolds shall not be located in unheated spaces.

Nitrogen for medical, or vivarium applications (typically tool use) is normally provided by dedicated high-pressure cylinders located in a medical gas closet, with distribution at pressures in the range of 1380 kPa (200 psi) and provision of local gas control panels. Systems are sized in accordance with NFPA-99. Where nitrogen is required for inhalation therapy, it shall be provided from a dedicated manifold gas supply system as a typical 380 kPa (55 psi) medical gas.

Specialty medical gasses shall be provided as local manifold cylinder systems (unless otherwise supported by demand requirements), dedicated for medical gas use.

## H.2 Distribution:

The use of intertied medical gas redundant risers and mains to preclude catastrophic single point failure, incorporation of backfeed insertion points, and service valving provisions is required and shall be thoroughly reviewed during system design to ensure system reliability and facilitate future renovation and maintenance with minimal disruption. Where buried installation of any medical gas line is required and cannot otherwise be avoided (such as from a bulk tank to a building), each individual medical gas line shall be enclosed in a continuous sleeve, which is then encased in a minimum of 150 mm (6 in.) thick by not less than 300 mm (12 in.) wide concrete barrier. Metallic warning tape shall be provided at the

top of the concrete encasement, and again half way between initial backfill and continuous grade, specifically indicating the type of piping service. Tracer wire shall be provided at each riser end of the buried service. Laboratory gas services do not typically require interconnected risers, however this may be necessary for carbon dioxide serving incubators and for critical control air systems. The extent of interconnected risers for laboratory services should be reviewed on a per-program basis.

Master and local area alarm panels to monitor line pressures and the status of supply equipment shall be provided for all medical gas systems. Monitoring shall utilize pressure switches (no mercury switches allowed) or contacts located downstream of the manifold. Two master alarm panels shall be provided for each medical gas supply system, wired in parallel to a single sensor for each condition. Audible and noncancellable visual signals shall be provided for main-line pressures and for changeover status of manifold systems. Master alarm panels shall be placed in two separate locations: the office or work area of the individual responsible for maintenance of the system, and at a second location monitored 24 hours per day, i.e. a telephone switchboard or security office. The maximum quantity and type of ventilators shall be established on a per program basis in determining sizing for oxygen and medical air systems.

Medical and vivaria gas systems shall be tested in accordance with NFPA-99, and in addition, all piping shall be tested at 20% above normal line pressure for a 24 hour period. Conventional laboratory gas systems shall be tested at not less than 1035 kPa (150 psi) for 24 hours. The A/E shall specify additional tests for specialized systems to insure system integrity. The only allowable pressure changes shall be those caused by temperature variations.

The required quantity of medical gas and vacuum outlets shall be verified on a per-program basis. In no case shall the minimum outlet quantity or locations be less that that specified in the most current edition of NFPA-99 or as recommended in the AIA Guidelines for Design and Construction of Health Care Facilities. Pressurized gas systems shall be sized so that at maximum demand the gas pressure at the outlet is not less than 21 kPa (3 psi) below the normal design pressure, except that pressure drop not to exceed 10% of system nominal operating pressure may be used for systems operating at or above 690 kPa (100 psi). Minimum pipe size for any service shall be 13 mm (1/2 in.). In addition, the project specifications shall include that:

- Only licensed plumbers or pipe fitters, certified as medical gas installers in accordance with the ANSI/ASSE Series 6010 Professional Qualification Standard for Medical Gas System Installers, by a qualified agency shall install medical and vivaria gas systems.

- Persons certified as medical gas inspectors or verifiers shall inspect new installations.
- The quality of medical and vivaria gas system brazing installed at the NIH shall be equivalent to the requirements of the Brazer performance qualification standard as modified by NFPA 99 for a Level 1 system.
- The medical gas contractor shall conduct initial testing of medical gas systems prior to system verification, in accordance with NFPA 99.
- Independent third party medical gas verifiers, qualified in accordance with the requirements of NFPA 99 and the ANSI/ASSE Series 6030 Professional Qualification Standards for Medical Gas Verifiers shall conduct systems verification. The verification procedure shall include all steps outlined in NFPA 99 and ASSE qualification standards.

Sufficient service and emergency shut-off valves shall be provided in accordance with NFPA-99, and as required to permit independent isolation of each building, floor, and major building wing. Valves shall be appropriately located, including use of locking and monitoring as appropriate. The use of three-valve capped bypass arrangements to permit emergency backfeeding and continuity of service during future maintenance and renovations is encouraged and should be coordinated with ORF during facility design.

Emergency shutoff valves are typically mounted at 1,650 mm (66 in.) AFF. Zone Valves for medical gas systems shall include pressure gauges inside of the valve box. Gas outlets shall be the quick-disconnect type, except 1,380 kPa (200 psi) nitrogen and surgical areas which shall be DISS type. Station outlets shall bear the label of approval as an assembly under reexamination source of UL and be designed to provide the following features unless noted otherwise.

- Conform to requirements of NFPA Standard 99.
- Preclude any mix of service and safety keyed to prevent accidental interchangeability of secondary equipment.
- Be capable of being flush mounted; self-sealing requiring no dust cover with quick coupling capability and equipped with an adjustable valve mechanism to compensate for mounting variations.
- Provide one-handed, single-thrust mounting and one-handed fingertip release of secondary equipment.
- Accept two-pronged connectors, each to its own function and both preventing twist and turn of the secondary equipment once connected.
- Have been pre-approved by NIH for compatibility with existing equipment and systems and for confirmation of appropriate type for the program function intended.

## I. Vivarium Gas for Animal Procedures:

Oxygen, carbon dioxide, and other gas services to vivaria shall be designed and installed with regards to cleanliness and reliability as an NFPA-99 Level 1 system, but shall be completely independent of medical gas systems serving humans. Gases critical to vivarium operations are typically provided as dedicated local cylinder supply systems, and should be independent of other lab areas. Primary supply/ reserve system status alarm shall be provided, including pressure alarm indication. Such systems shall be installed by installers certified in accordance with ASSE series 6010 requirements, and verified for purity by an independent third ASSE series 6030 party medical gas verifier as related to system cleanliness and delivered gas purity. An alarm panel to monitor line pressures and the status of supply equipment shall be provided. Monitoring shall be accomplished via pressures and switches and contacts located downstream of the manifold. All systems shall comply with the latest edition of NFPA 50, 56F, and 99 as applicable. The following gases are required for each functional area listed, unless otherwise verified with NIH program requirements. Reference the NIH space data sheets for each function.

Exhibit X8-8A Vivaria Gas Terminals for Animal Procedures

| Functional Area | Gas |
|---|---|
| Exam/treatment | Animal oxygen, Animal vacuum, and compressed air |
| Necropsy | Animal oxygen and compressed air |
| Prep/holding | Animal oxygen, animal vacuum, and compressed air |
| Surgery | Animal oxygen, animal vacuum, animal compressed air, animal nitrous oxide, and nitrogen. |

# Section 8-9: Central Vacuum



## 8-9-00 Design Requirements

### A. Description:

Central laboratory vacuum is typically required for each lab facility. Systems for laboratories shall be completely independent of medical (clinical) systems. Surgical vacuum may be required for vivarium areas, and is required for medical (clinical) functions. Waste Anesthetic Gas Disposal (EVAC/WAGD) systems are required for certain clinical areas (anesthetizing locations), but may not automatically be required for vivaria. Each vacuum system application shall be evaluated for the type of substance or products being evacuated and for the appropriate application of equipment type. The exhaust from the vacuum systems shall be discharged outdoors above the roof a minimum of 7.6 m (25 ft) from air intakes or other building openings and areas where persons may congregate, and shall be protected from the entry of insects, water, or debris. To prevent premature wearing of the pump because of backflow of condensate, a drip pocket, a minimum 250 mm (10 in.) in length, full line size, and a ball valve shall be installed at the exhaust port of each pump. Drip pockets are also required at the foot of exhaust risers. Exhaust lines shall be sized so as to minimize backpressure on the pump.

Vacuum systems shall comply with the following:

- Medical and surgical vacuum systems shall be completely independent of other systems and shall be compliant with NFPA-99.
- Medical, lab, and vivarium vacuum exhaust shall terminate a minimum of 6.0 m (20 ft) from any building opening, door, or air intake, or window.
- Medical vacuum shall provide vacuum level between 380mm (15 in.) and 560mm (22 in.) mercury at outlets. The system shall be sized for maximum pressure drop at peak demand to not exceed 75 mm (3 in.) Hg.
- WAGD/EVAC systems shall be provided upon consultation with the program use group anesthesiologist, and shall be sized on the basis of 50 l/min (1.75 cfm) per inlet, with no diversity. Only active type systems are permitted, typically conventional US standard “high-vacuum active” systems are utilized, connected to the serving medical gas mains in

the corridor or as a dedicated system. In some cases, low-vacuum active systems may be utilized where preferred by the use program, however passive systems are not permitted. Liquid ring vacuum pumps or regenerative blowers shall be utilized as the production source for WAGD/EVAC systems.

- Medical vacuum outlets shall include a slide bracket to accommodate a vacuum bottle for each outlet. Area alarm systems shall be provided in anesthetizing location areas and other life-support and critical care areas such as post anesthesia recovery. Area alarms shall provide audible and noncancellable visual signals when pressure drops below 300 mm (12 in.) Hg.
- A biohazard warning symbol shall be provided at each surgical medical or vivarium vacuum pump.

## B. Laboratory Vacuum:

### B.1 Vacuum Source:

Pumps, whenever possible, shall be of the single-stage, fully recirculating, liquid ring type, designed for use in chemical laboratory or chemical processing, constructed of stainless steel with corrosion resistant mechanical seals and elastomers compatible with laboratory chemical process vapors. The vacuum system should be insensitive to occasional ingestion of liquid slugs as may occur from improper trapping and use at vacuum inlets. A float or level switch shall be provided to limit seal water makeup to only the flow actually required. Pumps shall divert to once-thru operation and alarm upon any failure of adequate cooling water flow. Prior to selection of vacuum pumps, the A/E shall evaluate the substance being evacuated and compatibility of the system with any potential chemicals. The system design criteria shall be for 100% of the system peak load to remain upon failure of any one pump. All pumps shall alternate in the appropriate lead-lag sequence and include a pump exerciser function. Vacuum receivers shall be corrosion resistant and have automatic drain traps to remove moisture from the system. The determination to provide standby power shall be made on a per project basis. Local control systems with system operating status and alarm condition readout shall be provided at the equipment, and lead-lag-alternate-minimum run functions shall be included. A remote signal-to-building automation system shall be limited to a general fault alarm for each system source.

The LV system shall be capable of maintaining a vacuum of 480 mm (19 in.) Hg at the inlet terminal farthest from the central vacuum source under peak demand. If deeper vacuums are required, they shall be generated locally with special vacuum pumps in the laboratory or laboratory support area. The system or pumps shall be selected for an operational range of 560 mm (22 in.) to 600 mm (24 in.) Hg.

## B.2 Vacuum Distribution:

The system distribution and pump sizing shall be based on 0.25 standard l/s (0.5 cfm) at each vacuum inlet terminal. Standard laboratory diversity factors may be used if they can be properly validated. Where demand curves are based on flows of 0.47 standard L/s (1 cfm) rather than 0.25 l/s (0.5 cfm) (such as the ASPE General Laboratory Use Demand Curves), the increased flows of the curves shall be utilized with their appropriate diversity factors for all but the first five inlets on any branch, at which point the first five inlets on each line are sized at 0.25 l/s (0.5 cfm) without applying diversity. The pipe sizing shall be based on 76mm (3 in.) Hg as the total piping system pressure drop from the farthest terminal at peak design demand.

Primary services to each floor of a building wing shall be connected to respective supply risers, independent of other floors or building wings. Risers shall be located either inside the building wing served, or in a common area to multiple building wings. Runouts from horizontal piping serving drops to inlets shall be taken off above the centerline of the main or branch pipe and rise vertically at an angle of not less than 45° from vertical. Provision of adequate valving is of the utmost importance at the NIH. Valves shall be provided in such a manner as to facilitate maintenance with minimal disruption and to isolate systems for renovations and unexpected emergencies. Valves shall be provided at the base of each riser, at each riser connection, at branch piping to each laboratory equipment group, and at equipment requiring maintenance. Each floor distribution loop shall be provided with sectionalizing valves, such that a branch or portion of the loop may be shut down without disrupting the service to the entire floor or major portion of the facility. Valves shall be arranged to permit isolation of specific areas without affecting operation of adjacent spaces. All valves shall be arranged in an accessible manner. Where valves are located above ceilings, thorough coordination of piping services shall be required to ensure proper access for valve operation.

## C. Vivarium (Animal) Vacuum:

Where animal vacuum is required for animal surgical procedures or animal WAGD/EVAC, a separate dedicated vacuum system shall be provided. Animal vacuum systems shall not be combined with clinical medical vacuum. Vacuum systems for animal surgical procedures are designed utilizing equipment suitable for clinical surgical vacuum and similar design approach. A biohazard sign shall be provided at the vacuum equipment as indicated for clinical surgical vacuum systems. For limited applications, the use of local vacuum systems adjacent to the program area may be considered. Building-wide central animal surgical vacuum is typically not required. The use of vacuum for procedure rooms and safety enhancements shall be determined on a per project basis. WAGD/EVAC requirements for animal applications shall be determined through consultation with the program veterinarian,

and shall be based on low vacuum or high vacuum type active systems as appropriate to the program.

## 8-9-30 Design Guidance

A standing pressure test shall be performed after installing the vacuum system, including station inlets, but before attaching the vacuum lines to the vacuum pumps, receivers, and alarm switches. The test shall consist of subjecting the system to a pressure of 1,035 kPa (150 psi) gauge by means of oil-free, dry nitrogen or air. After allowance for temperature variation, the pressure at the end of 24 hours shall be within 35 kPa (5 psi) gauge of the initial pressure.

# Section 8-10: Natural Gas/Fuel Gas Systems



## 8-10-00 Design Requirements

Fuel gas piping is limited to natural gas that is supplied through site distribution mains from a Washington Gas source. Propane may be used for remote buildings when life-cycle costing justifies its installation over natural gas. Natural gas systems shall be designed per NFPA Standard 54/ANSI Z-223.1, *National Fuel Gas Code*. Propane/LPG systems shall be designed in accordance with NFPA-58 and NIH DFM requirements.

The natural gas piping system shall be designed to provide 0.03 (0.008) to 0.04 L/s (4 to 5 CFH) at each laboratory outlet at a pressure of 1750 Pa (7-inch w.g) Fuel gas piping distribution systems that serve laboratories shall be low-pressure systems, operating at 1750 Pa (7-inch w.g.). Welded medium pressure natural gas distribution systems of 14 (2) to 35 kPa (5 psi) may be used to serve the inlet pressure regulator in food service and mechanical areas, where justified by the gas load, and installed in full compliance with NFPA 54 and serving gas supplier requirements, including proper over-pressure protection. Gas services to kitchen appliances shall not exceed 14 kPa (2 psi) unless specifically required by individual equipment. Gas distribution systems to food service areas and mechanical equipment shall be separated from the laboratory gas distribution piping starting at the service entrance. For laboratories, the volume flow rate required shall be determined from the manufacturer's input ratings. If safely established, diversity may be used for the laboratory turret outlets, but equipment shall be considered at 100% use factor. Food service equipment loads shall not be diversified. Primary equipment loads shall not be diversified unless a control means to preclude simultaneous operation even under peak conditions is provided, and prior written approval of NIH and conformance with requirements of the serving gas supplier.

The design pressure loss in the gas piping system shall be such that the supply pressure at any piece of equipment is greater than the minimum pressure required for proper equipment operation. A pressure drop of 75 Pa (0.3 inches of water gauge) during periods of maximum design flow is to be used for sizing low-pressure gas installations. Pressure drop in medium pressure systems should not exceed 10% of the design distribution pressure.

Adequate number of valves shall be provided as described for compressed gas systems. A lever handle fuel gas shut-off valve shall be provided upstream of each cooking line, in addition to the required automatic gas shutoffs and individual appliance shut-offs. Shutoff valves shall be specifically designed and listed for fuel gas application and shall be appropriate type per UL listing guide, AGA, and ASME requirements in consideration of system operating pressure, type of fuel gas, and installation location. Valves 62 mm (2-1/2 in.) and smaller shall be ball type. Valves 75 mm (3 in.) and larger shall be eccentric plug type. Valves at gas service riser shall be eccentric plug type, wrench-operated. Shutoff valves shall be specifically listed for the appropriate fuel gas application and for use at the system operating pressure. All interior gas valves shall be actuated without requiring the use of tools. Gas services shall enter buildings above grade, and a main gas service plug valve and union or flange shall be provided prior to entrance to the building. Each laboratory floor shall have an isolation valve that is quickly accessible for emergency shutoff, located through consultation with the DFM, to permit emergency isolation of an individual floor of each building wing. An actuated valve may be required to facilitate operator initiation from each required egress or area of refuge, at the location as approved by DFM. The device shall be normally open and of the pneumatically or electrically operated stored-energy type to permit a minimum of two operations in the event of loss of air supply or power source. The valve shall be of fire-safe construction, designed for fuel gas service. Once the actuator is activated to shut off gas, it shall require manual intervention to re-open, such that safety conditions can be restored prior to reactivation.

Whenever equipment is on wheels or intended to be movable for regular cleaning or usage, the gas connection shall be made with a UL/ AGA listed epoxy-coated stainless steel commercial type gas connectors that is especially designed for movable equipment applications and includes a quick disconnect with integral shut-off and a properly assembled restraining device. All connectors shall be properly sized for the required flow rate based on equipment input requirements and maximum allowable pressure drop. Gas connections to laboratory equipment and fixed equipment shall be hard-piped, and unions shall not be permitted in concealed, unventilated spaces, including above ceilings. The final gas connection below the ceiling to laboratory fume hoods may be made with ASTM A539 welded steel tubing specifically designed for fuel gas lines; however, compression fittings shall not be utilized at any point in a fuel gas system, and joints shall be permitted only at each end. Couplings used in natural gas systems shall include appropriate thread stops and proper NPT pipe thread taper. Factory-furnished couplings at the end of threaded steel pipes that protect pipe threads shall not be used in the piping system in lieu of proper fittings because of the high incidence of leakage at these joints.

Services to each floor of a building wing shall be connected to respective supply risers, independent of other floors. Gas piping shall not route through electrical rooms or other potential sources of combustion, hazardous or critical spaces, or where subject to potential mechanical damage. Horizontal gas piping shall be graded to slope to drain towards the service entrance and risers at a slope of not less than 5 mm (3/16 in.) per 5 m (16 ft). Exposed gas piping in food service areas shall stand-off away from the wall at least 25mm (1 in.) to permit cleaning utilizing standoff clamps or other method suitable for wash down with minimal concealed surfaces to maintain sanitation. Gas regulators shall be vented to the outside and shall be at least 6.1 m (20 ft) from any air intake or building opening, turned down and screened, and sufficiently elevated to prevent blockage from snow or water. Regulators without external vents shall not be used with the exception of low pressure appliance regulators where approved by the serving gas supplier and in conformance with NFPA-54.

Fuel gas should not be piped to biosafety cabinets, consult with DOHS for approval. Gas cocks and turret outlets shall have 1/4-turn lever handles so that a quick visual observation can determine whether valves are open or closed.

## 8-10-30 Design Document Requirements

Gas piping shall be tested with an air pressure of 420 kPa (60 psi), with no pressure drop during a minimum of an 8 hour test period (other than temperature stabilization), and the test pressure and duration shall in no case be less than as required by NFPA 54 based on the total piping system volume. Proper procedures shall be included to isolate equipment and appurtenances from the test pressure in accordance with NFPA 54 requirements. Each gas piping joint, connection, valve, and source of potential leakage shall be tested. Only final connections to equipment may be tested with noncorrosive manufactured gas leak detector solution or sensitive electronic leak detection.

# Section 8-11: BSL3 & ABSL3 Biocontainment



## 8-11-00 Design Requirements

### A. BSL-3 Containment Barrier Piping Penetrations:

Penetrations into the containment barrier of BSL-3 shall be fully detailed in the construction documents, and shall require mock-ups to be constructed and tested prior to installation. Penetration details for equipment shall be coordinated with the equipment manufacturers. All penetrations shall be durable, sealed, and tested to meet the room tightness criteria for BSL-3 laboratories. Piping penetrations shall be rigidly braced to structure prior to penetrating the containment barrier and the seal should be visible for routine inspection and maintenance. Insulation shall terminate at the back face of the penetrated material, prior to the containment barrier. Escutcheons shall not be utilized, however a stainless steel washer or plate bedded in sealant and properly caulked to the penetrated material and piping may be provided. Copper and brass tubing shall not be embedded directly in masonry without protection. Where water supply stub-outs are embedded in masonry walls, stainless steel nipples should be used for corrosion resistance. Refer to "BSL-3 Testing, Validation, and Calibration" in Section 2 of the DRM.

Penetrations shall be sealed with a non-shrink corrosion resistant method and shall have some flexibility for removal for maintenance requirements. For detailed sealant requirements, see Chapter 4 Architectural Exhibit X4-7-A "BSL3 Caulking and Sealants".

MEP penetrations shall be gas tight and pass the following test: All door penetrations shall be sealed and room pulled to negative 250 Pa (0.036 psi); and maintained for the duration of the test. Subsequently smoke test shall be performed at all penetrations to include electrical outlets, duct penetrations, piping penetrations; smoke shall not demonstrate any visible disturbance indicating airflow through the penetration.

### B. Water Systems Serving BSL-3:

Water supplies to BSL-3 spaces shall be isolated from other functions with an approved backflow preventer installed outside containment prior to penetrating the containment bar-

rier. A single device may be provided for each individual penetration, or parallel devices to provide N+1 redundancy may be utilized to serve multiple suites.

Where the supply is from the building general laboratory water system, an ASSE 1015 (double check valve assembly) is adequate for containment barrier isolation. Where supply is direct from building potable water, an ASSE 1013 (reduced pressure principal) device is required.

Downstream of the isolation backflow preventers, distribution shall only serve process outlets within containment and water shall not be circulated back upstream of the containment barrier isolation backflow preventer. The engineer shall be diligent to ensure hot water is immediately available at use points, with delays to the most remote outlets not exceeding 15 to 25 seconds.

Unprotect potable water shall not be extended into containment. Outlets requiring potable supply direct from the domestic potable water system (such as emergency eyewash, showers, and toilet room/shower fixtures located in containment) shall be isolated from other functions with an ASSE 1013 backflow preventer, except that an ASSE 1015 backflow preventer is adequate for serving only toilet room/ shower-out room fixtures without hose-supplied outlets.

Backflow preventers are required for connections to high hazard equipment and shall be of appropriate type for the application and hazard, and should be located outside the containment barrier. Connections to tissue digesters and vacuum pumps shall consist of two ASSE 1013 devices in series if connected from potable water, or not less than a single ASSE 1013 device if supplied from lab water.

## C. High Purity Water Serving BSL-3:

The preferred method of supplying purified water to BSL-3 laboratories is through the use of dead-leg type RO water and subsequent local polishers within containment. Backflow protection shall be provided outside the containment barrier similar to other water systems serving BSL-3 and shall be constructed of stainless steel for compatibility. The water supply upstream of the backflow preventer may be shared and recirculated with the general purified water distribution serving other BSL-2 lab areas. UV sanitation and submicron filtration shall be provided an the water purification system, preferably at the return to the tank.

## C.1 Recirculation Systems:

Recirculation of fluids downstream of backflow preventers back into the supply side of the backflow preventer is prohibited. The use of local sub-loop recirculation (with no recirculation back to the supply side of the backflow preventer) may be considered.

Purified water systems shall not circulate between outlets from one lab into another. Direct return systems (with a direct return connection from each lab to a return main) and check valves at supply outlets shall be provided where recirculation is utilized. The A/E shall ensure sufficient pump flow and supply to demand ratio to ensure positive loop pressure and adequate flow under periods of peak demand.

## C.2 Dedicated Systems:

A dedicated distribution system isolated from the RO production and other systems with an appropriate air gap (storage tank configured as a break tank arrangement with filtered overflow vent, vacuum protection where required, and redundant high level controls), or a completely independent system may be used for BSL-3, but is not required where meeting the requirements of this section. Backflow protection on the makeup supply to the RO or production system shall utilize an ASSE 1013 device.

## D. Animal Drinking Water Systems Serving BSL-3:

The use of bottled or packaged water versus automated drinking water systems shall be evaluated through consultation with DOHS, ORF, and the program veterinarian. Detailed design drawings for animal drinking water systems shall be submitted for review during project design.

Where automatic systems are utilized, the approach and need for cross contamination protection between species, agents, and building spaces shall be considered in the design of the distribution system and determined through consultation with DOHS, ORF, and the veterinarian. Cross contamination protection within the containment system can generally be provided by use of an ASSE 1015 backflow preventer located upstream of pressure reducing/ flushing stations for common or multiple zones, and through use of distribution designs that avoid serpentine layouts of piping which permit flow from one suite into another. The system shall include provisions for removal and capping of nozzle outlets and use of a chemical proportioner or steam in place (SIP) to permit complete sterilization.

Penetration protection and pipe mounting details shall meet requirements for other systems. Plastic piping shall not be utilized inside containment or downstream of system backflow preventers. Plastic piping supports should be avoided.

Recirculating systems are not permitted due to risks of cross contamination. Flushing lines from the system shall terminate at a normally used drain within the containment barrier, and flushing lines for individual rooms shall discharge within the same room served. Production systems (RO, acidification, etc.) shall be located outside the containment barrier in clean space. Where any controls are located inside containment, components shall be constructed to permit and withstand fumigation. System controls or valving should permit flushing control valves to be individually manually activated or disabled.

Supply shall be taken directly from building potable water and isolated from all other systems with an ASSE 1013 backflow preventer located outside the containment barrier. Any portion of the system downstream of the ASSE 1013 backflow preventer shall only serve BSL-3 areas.

## E. Vacuum Systems Serving BSL-3:

The use of disinfectant traps and hydrophobic HEPA filters are required at each point of use, including biosafety cabinets and aerosol chambers. The preferred method for generating vacuum is through point of use portable vacuum pumps, however; central systems may be utilized. Portable pumps are low maintenance, minimize piping out of containment, and may be cost effectively sterilized, discarded and replaced upon malfunction. Where central systems are selected, they shall be dedicated to BSL-3 and shall not serve other areas.

### E.1 Central Systems:

Hydrophobic HEPA filters arranged in parallel shall be provided at the vacuum pump to protect the pump from contaminated fluids due to improper trapping or damaged filters at the point of use. A liquids separator is required prior to the filter and shall discharge to the same waste system as the waste system serving the labs.

Connections from this system shall not be open into the mechanical room. The drain from the separator or receiver shall be hard piped into a minimum 75 mm (3 in.) diameter individually vented deep seal trap, and a floor drain with time-clock actuated trap primer and deep seal trap shall be provided on the branch line serving the vacuum pump receiver to protect from sewage backflow. Where the vacuum system uses a check valve to seal the discharge from the outlet of the tank or receiver, a full size vent shall be provided on the inlet side of the trap to the exterior to permit the check valve to properly seal and preclude pressure oscillations in the drain system.

Isolation valves and decontamination ports shall be provided to allow decontamination of the tank, pump, and vacuum lines of the system. Where liquid ring vacuum pumps are util-

ized, double ASSE 1013 backflow preventers (two devices in series) are required at the equipment connection.

Seal liquid from liquid ring vacuum pumps may be recirculated within the system, but shall not be collected and reused for any other purpose. The use of disinfectant seal liquids (such as alcohols) may be considered, but is not required. Locating the vacuum pump in a negatively pressurized room is recommended. Exhaust from the vacuum pump and vent lines for the receiver/liquid separator shall be separately piped above the roof and discharge a minimum of 7.6 m (25 ft) from any air intake, building opening, or areas where persons may be normally present, at locations approved in consideration of the facility risk assessment.

## F. Lab and Vivarium Gasses Serving BSL-3:

No special provisions are necessary for pressurized gases into BSL-3 containment labs serving typical turrets. Lab gas outlets in BSL-3 spaces typically do not represent significant hazard, primarily as outlets typically do not open into primary containment and systems are normally pressurized. Gas cylinders should not be located inside containment spaces and shut-off valves should be provided for each penetration into containment to permit independent isolation of each service. As with all systems, the engineer shall be especially cognizant of gas (especially air) purity levels required for certain equipment (such as aerosol inhalation chambers) to maintain research integrity. Pressurized gas systems should not be connected to primary containment devices. Where pressurized gas services will be utilized for required procedures in primary containment equipment such as aerosol inhalation chambers, the service line shall be provided with a loaded check valve device near the point of use or barrier penetration, designed to be leak tight under static and back-pressure conditions for use with small molecule gasses (such as helium); or alternative protection as approved by DOHS. Vivarium gasses shall include cross contamination protection if serving other areas. Gas services shall be completely independent of systems (including bulk tanks) serving humans.

Provision of fuel gas service within containment is often unnecessary and should be avoided where possible.

## G. Critical Air Serving BSL-3 Containment:

Air systems that serve critical containment controls and critical containment barrier components shall be arranged to preclude single point failures and be provided with full redundancy from two independent remote sources. The primary air source may be from building laboratory, dedicated control, or central plant air arranged to provide N+1 redundancy with compressors on building emergency power. The secondary source may be from a dedicated air compressor, receiver, or any of the above that is remotely located from the primary

system and connected in such a manner as to preclude single point failure issues. The system shall be arranged to ensure that upon failure of normal power and failure of emergency power, sufficient air at adequate pressure is available to operate and return critical controls to a safe position and will not be lost through open outlets or non-critical use points. This may require the use of a dedicated critical air storage tank with supply inlet check valve, automatic control valves, UPS controlled compressor or alternative means as approved by NIH.

## H. Waste and Vent Serving BSL-3

### H.1 General Requirements:

Waste and vent openings from other piping systems are not permitted within the containment barrier, and openings from containment piping systems shall not be located outside the respective level of containment. Radiological waste shall not be discharged through the piping system.

Waste should discharge by gravity to the sanitary sewer, without use of lift stations. Where lift stations are required on any system necessitating treatment and such treatment cannot be provided prior to lifting, prior approval of DOHS and ORF must be obtained, and will only be considered for BSL-3 applications. Where such pumped discharge is accepted, the system shall be located in a negatively pressurized room served with handwash provisions, and shall incorporate features such as decontamination ports, use of only duplex pneumatic ejectors, steam jet ejectors, or lethal service pumps, receiver transfer and decontamination capability, actuated normally closed valves on effluent pressurized discharge, and use of corrosion resistant waste receivers located in a containment sump.

Water fed trap primers are not utilized in containment as these can flush disinfectants from trap seals. Operational protocol includes maintenance of disinfectant trap seals. Grinders should not be utilized in BSL-3 due to potential for aerosolization of infectious wastes, and such wastes . shall not be intentionally disposed through building drainage systems. Discharge from tissue digesters shall be appropriately pH neutralized, preferably at the source.

Where indirect waste connections are required for incidental lab equipment (such as ice machines and small equipment) drainage connections should be made to an adjacent wye-branch sink tailpiece at the trap inlet and must be made within the same suite. Discharging such waste to a normally used fixture minimizes potential for a dry trap or loss of disinfectant and avoids the installation of unnecessary floor drains (which should not be located in containment labs) or concealed drain openings and the need for additional SOP's. Portable condensate pumps to lift waste from ice machines to sink trap inlets within containment may

also be utilized. Showers shall not be used as a waste receptor for indirect waste, regardless of volume.

Autoclave Capture Hoods: Discharge condensate to drain openings on the same side of containment as the respective hood to preclude piped openings through the containment barrier. On the clean side, hoods typically spill to the floor sink serving the autoclave. On the dirty side, hoods may be piped to spill to a sink or sink drain tailpiece within containment, or allowances for hanging a small container (that can be manually emptied) is acceptable.

Drain openings in insectaries shall be provided with durable, tight fitting double layer stainless steel screens (not larger than #30 USA sieve, verify with program) and sinks should also include normally closed valves at the trap inlet/ fixture tailpiece. Floor drains should be avoided in insectaries.

## H.2 BSL-3 Waste and Vent System:

Waste and vent is arranged similar to general lab waste and vent systems. Effluent decontamination is not generally required or desirable at BSL-3 as practice precludes discharge of infectious waste through drains and risk does not typically warrant use. Incorporation of proper validated systems represents significant design issues and where any type of treatment system is provided, the arrangement shall be pre-approved by DOHS and ORF and designed to preclude loss of lab operation due to maintenance or malfunction. HEPA filtered vents, negative pressure vents, double-contained waste, etc. are not typically provided for BSL-3 waste systems, and are typically only considered where effluent decontamination is determined necessary for the program by DOHS. In many cases, the need for effluent treatment can be avoided through facility design, animal housing and transport, and proper lab operating procedures. The use of a disinfectant filled transparent carboy serving an individual valved sink outlet can often serve as a substitute for plumbed drain connections. Any decisions to utilize effluent treatment or decontamination systems should not be taken lightly and dialogue with NIH DOHS is encouraged prior to any commitments. Proper validatable systems and appropriate waste and vent design for effective biowaste systems involves a number of complex issues as well as on-going maintenance concerns that would typically be unwarranted at BSL-3. Related provisions are not covered by the scope of this document and requirements may be provided by DOHS on an individual basis as deemed necessary..

Waste systems shall be atmospherically vented with deep seal traps provided for all drain inlets within containment. Trap seal depth shall be at least 50 mm (2 in.) greater than the serving HVAC fan static pressure, but not less than 125 mm (5 in.) measured from the crown weir to the top of the dip of the trap. Such traps typically require field construction,

and shall be detailed to maintain self-scouring properties. Floor drains/floor sinks shall be avoided in containment. Where floor drains are necessary and depending on agents utilized, effluent treatment and other special provisions may be required, consult with NIH DOHS for direction.

Vents shall terminate above the roof at least 7.6 m (25 ft) from air intakes, building openings, or areas where persons may congregate.

All drain inlets within containment should discharge to the waste system serving BSL-3, including lab sinks, aerosol and dirty change room showers, mop sinks, and other fixtures on the dirty side of the anteroom. Drains from gloveboxes and similar primary containment devices shall not be connected to building waste and vent systems.

The sterilized effluent from BSL-3 autoclaves may discharge through the sanitary system or general building lab waste system as an indirect connection through a floor sink. The drain receptor shall be located on the clean side of the bioseal, (including within the clean utility access area). Connecting to the sanitary system allows the use of conventional cast iron piping rather than high temperature rated corrosion resistant materials as required for where lab waste is utilized and reduces size and temperature effects on any facility pH treatment systems.

Waste pipe cleanout access should be arranged similar to other piping penetrations to maintain integrity of the containment barrier, typically arranged as a threaded capped or plugged pipe extension through wall. System piping materials shall be compatible with the range of disinfectants to be used within the lab, with the preferred piping material typically as fusion jointed polypropylene.

## I. Liquid Nitrogen Serving BSL-3:

Dynamic vacuum jacketing is not permitted, systems shall be insulated with static (passive) vacuum jacketing only. As piping penetrations must meet requirements for other systems, sufficient details must be included in the design drawings for sleeve and penetration requirements to facilitate proper installation during construction, especially where the distribution lines will be provided during fit-out. Flexible and corrugated connectors are not acceptable for barrier penetrations, but may be used inside the laboratory. Where dewars are utilized, they shall be located outside containment.

# J. Plumbing Fixtures Serving BSL-3

## J.1 Faucets:

As with all NIH laboratories, faucets within containment are protected with gooseneck type spouts fitted with integral ASSE 1001 atmospheric vacuum breakers. Hands-free faucets shall be either electrically hard-wire sensor operated or foot pedal actuated with slow-close valves and elongated flip-up pedals to permit cleaning. Battery-actuated faucets and faucets which operate with hands, wrist or elbow are not acceptable. Conventional knee-operated valves are not desirable due to excessive maintenance. Laminar flow non-aerating/ non-splash outlets shall be utilized. Flow rates for handwash faucets shall not be less than 8.0 l/min (2 gal/min). Hand wash faucets are required to be hands-free type, no over-rides to complete hands-free operation (as defined above) will be permitted.

## J.2 Showers:

Showers shall provide a minimum flow rate of 10 l/min (2.5 gal/min), and meet requirements outlined elsewhere in the DRM. Hand-held showers shall not be utilized except where specifically required for barrier-free compliance. The required fixture count shall be evaluated considering throughput requirements.

## J.3 Water Closets:

Where a watercloset must clear a deep seal trap (due to fixture location inside containment), blowout flushing action wall mount 13.5 liter per flush (3.5 gal/flush) closet shall be required to preclude stoppages and clear traps. The deep seal P-trap shall be located directly below the vertical fixture waste (as close as possible to the fixture) and vented downstream. The trap shall have a vertical inlet and be constructed with a total of four 45-degree ells, the first three of which shall be close coupled together, and the fourth one at the discharge extended as necessary to create the required trap seal depth. Preferred location for water closets is outside of containment on the clean side of showers, thought this may not always be possible.

## J.4 Stainless Steel Sinks

Where stainless steel sinks are utilized, surface undercoating and sound-deadening pads shall be omitted, due to sharp edges, porosity, and cleaning issues.

## J.5 Mop Sinks:

Service sinks within containment shall be constructed of enameled cast iron or stainless steel. Faucet outlet shall be provided with a vacuum breaker.

## J.6 Fixture Trap and Supply Insulation Kits:

Insulation kits shall not be used in containment.

## J.7 Floor Drains and Floor Sinks:

Stainless steel type with provisions for gas-tight closure where installed within containment. Floor drains/floor sinks should be avoided in BSL-3. Where drains are provided with approval of DOHS, drains shall be designed to allow interception of solids for autoclaving.

# K. Special Materials and Equipment

Materials exposed within containment shall be free of sharp or protruding edges and arranged to minimize risk of penetrating protective garments or inflicting injury to personnel. Materials shall be evaluated for compatibility with fumigation and cleaning agents. Light wall pipe and tubing, plastic piping, and materials subject to corrosion in contact with masonry shall not be embedded in concrete. Where recessed box devices are used (such as for hose stations, emergency shower actuation, etc.), the assembly shall be arranged to preclude breaching the containment barrier. The box shall be constructed of stainless steel with a solid back and sides, and all penetrations into the box shall consist of weld-sealed pipe inlet and outlet lines to maintain rigid, gas-tight penetrations. The box design shall include an appropriate surface flange to permit sealing the device to the containment barrier wall construction, and be arranged to provide a gas-tight finished installation.

## K.1 Piping Insulation

Insulation should generally be terminated just prior to the containment barrier with piping locations carefully planned to minimize need for insulation inside containment. Where exposed piping with insulation is determined necessary, the insulation must include a non-porous impact resistant jacket that is readily cleanable with sealed joints and compatible with the range of fumigation agents to be utilized. Prefabricated insulation and encasement systems are available and may be evaluated for this purpose.

## K.2 Piping Identification

Dedicated piping services specific to containment spaces shall clearly designate the specific function to minimize misapplication and risk of cross connections with other systems. For example, laboratory water serving BSL-3 would be designated “LCW-3”, “LHW-3” etc. Vacuum piping serving BSL-3 laboratories shall include the universal biohazard sign at piping and at equipment, and pipe tag color code shall be red with black letters.

## K.3 HEPA Filters:

Assembly shall be certified HEPA type at least 99.97% efficient at 0.3 micron, moisture resistant (hydrophobic) membrane with a leak tight frame and seals to avoid bypass leakage,

and stainless steel housing. PTFE filter membranes are typically utilized for in-line filters, sterilizing grade to provide at least the above indicated efficiency for virus particles in gas and liquid streams and validated as an assembly for efficiency and leak integrity by the manufacturer and again after installation. The filter selection shall provide the required capture efficiency at the minimum and maximum system operating velocity and shall be sized as required for airflow rate, velocity, and permissible pressure drop under loaded conditions. Where steam sterilization is utilized, filters shall be compatible without deterioration. Isolation valves and decontamination ports shall be provided at filter inlet and outlet, with a tight sealing threaded cap. Assembly shall be compatible for complete gaseous or vapor-phase decontamination and shall be installed vertically to preclude moisture accumulation. A valved and capped drain port is required for filters on vacuum systems. Gas-tight connections are required at least up to the first filter body; and the type of connection shall maintain tight seal under anticipated system vibration and thermal cycling conditions. The filter shall be arranged for in-place validation, and the approach to validation shall be documented in the basis of design or SOP's, as approved by DOHS. Bio-waste vent filtration is discussed in NIH Design Requirements Manual for BSL-4 containment. In the event bio-waste systems are required at BSL-3, obtain NIH DOHS approval.

### K.4 Decontamination Ports:

All decontamination ports shall be fitted with tight sealing threaded caps or plugs to preclude a direct opening in case of accidental operation of a valve.

## L. General BSL-3 Biocontainment Plumbing Requirements:

### L.1 Pipe Routing:

Piping systems not serving BSL-3 shall not be routed in containment areas. Avoid routing piping above or buried under slabs below major electrical or data/communications equipment areas, effluent decontamination room, or similar critical spaces except where otherwise unavoidable such as piping serving such spaces. Piping shall not be located above any panelboards or switchgear, including required service areas for such equipment. Piping below grade will avoid (in as much as practicable) routings below major infrastructure equipment. Exposed piping shall be minimized in BSL-3 containment and vivarium spaces. Piping services shall be routed and protected to minimize risks from mechanical damage. There should be no open connections from piping systems within containment, and piping serving the clean side of the containment barrier should be located outside the containment barrier.

## L.2 Pipe Support and Mounting:

Careful consideration shall be applied to selection of support and mounting means and piping should generally stand away from finished surfaces at least 25 mm (1 in.) to promote cleanability, decontamination, minimize concealed spaces, and not present sharp or protruding surfaces.

## L.3 Isolation Valves:

Each pressurized piping penetration from outside into containment shall be provided with a shutoff valve. Each equipment connection shall include isolation valves.

## L.4 Service Access Panels:

Access panels and similar openings through containment barrier walls or ceilings shall be avoided. In many cases, piping and service valves may be located outside the containment barrier in interstitial spaces, adjacent rooms, surrounding corridors, etc. Where this is not possible, the recommended approach is to drop piping out of the ceiling or wall to provide exposed valves etc., and then loop back into the wall or ceiling, with all pipe penetrations properly sealed. Alternatively, the use of full stainless steel access cabinets with a closed back and sides and stainless steel pipe inlets weld sealed to the box can be utilized to provide a sealed box arrangement. Special access doors designs are generally discouraged but may be permitted for certain cases with NIH approval.

## L.5 Containment Autoclave Chamber Pressure Relief:

Provisions shall be incorporated for the safe discharge of chamber pressure relief devices. The selected arrangement shall not compromise relief of overpressure conditions or allow escape of viable agent due to leakage, discharge, or malfunction. For BSL-3 applications, the use of a combination spring type pressure relief valve with lower pressure inlet rupture disk and incorporation of a burst indicator/pressure sensor is adequate, with discharge piping to a safe location consistent with the risk assessment. Where the downstream lines are routed to exterior or otherwise extensively piped (not typically required), or where provision of HEPA filters is required by the risk assessment, the effects of built-up and superimposed backpressure shall be considered in selecting the devices and downstream flow path, and all components shall be arranged to permit decontamination. The arrangement must ensure an adequately sized, open relief path is constantly available, and the relief lines are not subject to backpressure or cross contamination from other sources.

# 8-11-10 Design Guidance

## A. Seismic Accommodation:

In areas of seismic activity, special accommodation shall be provided to preclude breach of containment barrier, shearing of piping, or critical equipment damage due to differential movements caused by seismic activity. Such analysis and accommodation shall be performed by qualified structural and mechanical engineers in coordination with ORF and DOHS.

# 8-11-20 Design Information

The A/E shall refer to Sections 2-5 and 2-6 in Chapter 2 and the preceding sections of this chapter and make a determination of all applicable provisions that are to be incorporated into the design of the biocontainment facility.

# 8-11-30 Design Document Requirements

## A. Special Test and Inspection Requirements:

Systems shall be inspected throughout installation to ensure conformance with the requirements of the DRM. In addition, the following specific issues shall be addressed as part of quality control, testing, and commissioning plans. This section identifies some of the specific items to be reviewed and inspected within the plumbing discipline. It is intended to identify commissioning requirements, or to be all inclusive.

### A.1 All Piping Systems:

Test completed system to assure no cross connections exist between inlets in containment and non-contained spaces, between piping systems, and between containment levels, up to the point of intended separation. Standing pressure test at least 1.5 times design operating pressure for 8 hours. Penetrations properly sealed, mounting, support, and pipe protection arrangements appropriate for application. All systems properly identified with system-specific text.

### A.2 Water Systems and Backflow Preventers:

Certify performance annually for testable devices. Non-testable devices (such as atmospheric vacuum breakers at faucets) shall be replaced at intervals not to exceed every 5 years. Inspection during installation to ensure all specified devices present and unconcealed, no unprotected cross connections, and each outlet served from proper segregated

systems in accordance with the DRM. System cleanliness maintained during installation. No recirculation back to upstream side of backflow preventers. Required minimum residual pressure available at use point. Emergency fixtures properly connected to potable water, operational and with required backflow protection.

## A.3 Animal Drinking Water:

System cleanliness maintained during installation. System connected directly to potable source, required backflow preventers present and properly arranged. Proper distribution pressure, mounting arrangement, and location of flush lines. System cleaned and required water quality verified at each room. Alarm functions operational and properly calibrated.

## A.4 Vacuum Systems:

Test completed system to assure no cross connections exist between inlets in containment and non-contained spaces or between containment levels. The minimum leak integrity test for the vacuum system shall be 1035 kPa (150 psi) using compressed air held for 8 hours. Vacuum systems properly connected to piping systems and exhausted in accordance with the DRM. Reference commissioning requirements.

## A.5 Waste and Vent Systems:

Test completed system to assure no cross connections exist between inlets in containment and non-contained spaces or between containment levels. Provide final test for systems integrity after traps are filled as described elsewhere in the DRM for general waste systems. Check proper pipe slope, minimal horizontal offsets, correct fitting type/ application, and venting arrangement verified. Cleanout type/ provisions appropriate per penetration requirements. Trap seals in biowaste systems hold tight with at least 75 mm (3 in) w.g. trap seal remaining under actual system HVAC fan tests.

## A.6 Critical Control Air:

Required delivery pressure and volume present in normal and failure conditions for primary and reserve system. Required redundancies present to ensure required pressure and volume of critical air maintained under conditions of discharge of entire air supply from other portions of system, including conditions of a system failure. All alarms, sensors, and components calibrated and proven. Reference the commissioning requirements.

## A.7 Plumbing Fixtures and Equipment:

Tested for proper operation, flow and pressure. Correct fixtures installed at each location in conformance with DRM. Gas-tight drains installed and provide required gas-tight seal (test with traps dry). Sediment baskets/ strainers present where required. Fixtures properly caulked. Each equipment item checked for proper connection to respective systems.

## A.8 HEPA Filters:

Required devices present. Certify performance of complete assembly (filter as installed in housing) after installation. Threaded caps installed for all decontamination ports. See commissioning requirements in Section 1-7. Filter properly located, arranged to permit decontamination, validation, and servicing and arranged in a visible, readily accessible manner.

# Fire Protection

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# Section 9-1: Fire Protection Design Considerations



## 9-1-00 Design Requirements

The following design requirements apply to all fire protection systems. The engineering goals and objectives are to provide uniformity of design; combine the best overall economy with suitability of design; and be compatible with all other building systems. Provision shall be made for the addition of future expansion as determined by the NIH on a project-by-project basis.

Fire protection design shall follow the National Fire Protection Association (NFPA) National Fire Codes (NFC), International Fire Code (IFC), and the International Building Code (IBC), unless specifically altered or amended in this document. NFPA-5000 Building Construction and Safety Code is not utilized. When a conflict between the various code requirements exists, the most stringent/conservative standard shall apply. All portions of the NFPA NFC shall be followed including appendices, recommended practices, interim amendments, and formal interpretations. The A/E shall interpret only NFPA NFC use of the “should” as “shall” (i.e., must be followed) at all times. Any departure from NFPA NFC or IBC requirements must be clearly delineated in the A/E’s “Fire Protection Engineering Analysis,” if required (see requirement noted below), or other project correspondence, along with justification of the departure.

### A. Authority Having Jurisdiction:

The NIH Division of the Fire Marshal (DFM) is the AHJ defined in the NFPA and IFC requirements

# 9-1-10 Design Guidance

## A. Type of Construction:

The construction type selected shall, at minimum, meet the lowest classification required by the IBC for the proposed occupancy, based on occupancy, building height, building area, and other factors, as identified in the IBC. NIH fire hazard classification for laboratory areas is considered Class “B” per NFPA 45 definitions.

## B. Occupancy Classification:

Occupancy classification shall be per NFPA101 LSC. Laboratories and adjunct areas are classified as “Industrial”; animal holding facilities are classified as “Storage.”

## C. Fire-Resistant Materials and Construction:

All laboratory corridor walls shall have a minimum one hour fire rating. All one hour fire-rated partitions shall have 45 minute opening protection. Each vision panel shall not exceed 0.84sq m (9 sq ft). Open storage in the laboratories is not permitted, on a horizontal plane, within 0.46 m (18 in.) of the sprinkler deflectors (as measured vertically from the bottom of the sprinkler deflector to the horizontal plane). Enclosed perimeter storage (i.e., within cabinets) to the underside of the ceiling is permitted. In areas that also have a pressure differential at the ceiling, which can affect the operation characteristics of the concealed heads, the gasketed concealed heads shall be specifically listed for use in ceilings with pressure differentials.

## D. Flammable Storage Cabinets:

A flammable storage cabinet (FSC) constructed of metal shall be provided in each laboratory. Additional FSC’s shall be provided per NFPA 45 requirements. The exterior of all FSC’s shall be appropriately signed. The FSC shall be located as remotely as possible from the exit doors of the laboratory and shall not be installed beneath fume hoods. FSC’s shall not be located in corridors. The integrity of the FSC shall not be compromised by its mounting method. The FSC shall not be vented.

# 9-1-20 Design Information

The A/E shall use and comply with the design and safety guidelines, and references listed below, and other safety guidelines received from the NIH Project Officer or as required by the program. The A/E shall utilize the latest editions of reference design and safety guidelines available at the time of the design contract award.

## A. References

- National Fire Codes, all volumes, National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101, with the exception of NFPA-5000 Building Construction and Safety Code.
- The International Building Code (IBC)
- The International Building Code and the International Plumbing Code: International Code Council, Inc., and Building Officials and Code Administrators (BOCA) International, Inc.: 4051 West Flossmoor Road, Country Club Hills, IL 60477-5795.

# 9-1-30 Design Document Requirements

## A. Listed Equipment and Valves:

All fire protection devices, equipment, and materials shall be listed for the intended use. “Listed” is defined as equipment and materials that are identified in the Factory Mutual Research (FM) Approval Guide and/or the various directories of Underwriters Laboratories (UL). Testing by another nationally recognized laboratory may be approved by DFM on a case-by-case basis.

## B. Fire Protection Submission Guidelines:

The A/E shall provide language in the contract documents to reference the use of the “Fire Protection Submission Guidelines” for all fire protection system(s) in government owned facilities. This manual contains the requirements for design and construction submissions as well as construction submittals and inspections.

## C. Fire Hydrants

Construction contract drawings shall show the locations of all hydrants that are intended to protect a new or renovated facility.

- Hydrant and standard thrust block details shall be provided.

## D. Fire Alarms

Documents shall include system reprogramming, modification of graphic interfaces, and up-dating of system as-built drawings.

## E. Self Luminous Signs

Project specifications shall include a reporting requirement to immediately contact DRS (301) 496-5774 or 911, from an in-house campus phone, to report damaged or broken signs and to receive removal instructions and procedures.

# Section 9-2: Fire Suppression Systems



## 9-2-00 Design Requirements

### A. Automatic Sprinkler Systems:

### A.1 General Requirements:

All new occupied facilities and/or additions over 185 $m^2$ (2,000 $ft^2$) shall be sprinklered for compliance with the Federal Fire Safety Act of 1992. Facilities smaller than 185 $m^2$ (2,000 $ft^2$) may be exempted only with prior written approval of the NIH Fire Marshal.

Major modifications, renovations, and alterations to an unsprinklered building shall include the provision of sprinklers in the renovated areas with provision of blanked-off connections of suitable size to provide future sprinkler protection in other areas of the facility. Smaller modifications, renovations, and alterations shall, whenever feasible, include the provision of capped-off sprinkler piping in order to facilitate the future installation per NIH policy to provide sprinkler protection in all occupied facilities. The capped-off sprinkler piping shall be sized in accordance with the ordinary hazard pipe schedule method described in NFPA 13.

Sprinkler locations shall not be shown on the contract drawings, with the exception of special design areas (e.g., water curtains, aesthetically sensitive areas). Sprinkler locations at special design areas, if shown, shall be designed by a registered fire protection engineer or a National Institute for Certification in Engineering Technologies (NICET) Level III or IV sprinkler designer. Where sprinklers are shown, provide the following statement noted on each drawing: “Sprinkler locations have been shown for suggested and illustrative purposes only. Final sprinkler locations shall be coordinated in the field based on NFPA 13 spacing requirements. Sprinkler system shop drawings shall be prepared and submitted in accordance with NFPA 13 spacing requirements.” Final (for construction) fire protection drawings and hydraulic calculations shall be sealed by a registered professional engineer experienced in fire protection, except that drawings and calculations sealed by a NICET Level III

or IV sprinkler designer may be accepted for Bethesda campus projects submitted to the NIH DFM.

Sprinkler temperature rating shall be between 68°C (154°F) and 80°C (176°F) for all NIH facilities/occupancies except for the following:

- Sprinklers designed for 93°C (200°F) shall be used in electric closets.
- High-temperature sprinklers rated at 141°C (286°F) with sprinkler head guards shall be used in autoclave areas, mechanical rooms, electrical rooms, electrical switchgear and transformer rooms, and any other areas in which high temperatures are routinely experienced.
- For cold rooms and freezers the temperature rating of sprinkler heads shall be as above but the type of sprinkler shall be fusible link type. Frangible bulb type is not accepted.

For elevator machine rooms and elevator hoist way requirements, see Vertical Transportation Chapter 4 Section 4-6-10-D.4. “Sprinklers in Elevator Machine Room:”

Flow control (on/off) sprinklers are not permitted. Dry pendant type sprinklers shall be provided in cold rooms.

Installation of a backflow preventer on the sprinkler supply main shall be provided for all new sprinkler installations. The backflow preventer shall be selected to minimize friction loss through the device. Incoming fire service backflow preventers shall be ASSE 1048 or ASSE 1047 type (as appropriate). The backflow preventer shall be located downstream of the system isolation valve or post indicator valve.

An interior Class I standpipe system shall be provided if the facility has two or more stories above grade or more than one story below grade. An interior Class I standpipe system shall be provided if the travel distance from the primary FD vehicle access point to any point in the building is 61 m (200 ft) or greater. Class II and III standpipe systems are not permitted. Interior Class I standpipe system hose valves shall be provided in the following locations (IBC and NFPA 14):

- On each floor level of every required stairway. Intermediate landing locations not required.
- On each side of horizontal exits.
- In every exit passageway at any entrance from the exit passageway to other areas of a building.
- Inside the roof access stair. Outside roof hose/connection not required.
- At the most remote portion of each floor or story, within 46 m (150 ft) of a FD hose valve (sprinklered or unsprinklered). The distance shall be measured at right angles in the

normal exit access path. The AHJ is authorized to require that additional hose connections are provided in approved locations during the design phase of the project.

Standpipes shall be maintained in accordance with NFPA 241 during new construction, demolition, modifications, renovations, and alterations of existing NIH facilities.

At least one FD connection shall be within 30 m (100 ft) of a fire hydrant. If any plan dimension of the building is greater than 46 m, (150 ft), then a second remote FD connection shall be provided.

## 9-2-10 Design Guidance

### A. Automatic Sprinkler Systems:

#### A.1 Common Design Parameters:

All laboratories are classified as Ordinary Hazard Group 2. All sprinkler system designs shall meet, at a minimum, NFPA 13 Ordinary Group 2 spacing and hydraulic requirements.

In office buildings that do not contain mixed use laboratories, light hazard occupancies group spacing and hydraulic requirements may be provided with approval by the Project Officer and DFM.

A minimum of a 10% margin below the available water supply curve shall be provided in the hydraulic calculation of fire protection systems. The sprinkler design areas shall comply with NFPA-13 except that reduction of design area for use of quick response sprinklers etc. is not permitted.

Wet pipe sprinklers shall be used, except in areas subject to temperatures below 4°C (40°F). The minimum slope toward the main drain of the system branch lines shall be 4 mm/m (5 in. per 100 ft). The minimum slope toward the main drain of the system mains shall be 2 mm/m (2.5 in. per 100 ft). The maximum number of dry pendant or dry sidewall sprinklers shall be limited to 25 sprinklers per system.

All exterior sprinkler supply mains shall be adequately protected from freezing by proper burial depths in accordance with NFPA 24. Sprinkler piping exposed to freezing temperatures shall be part of a dry pipe system or, in instances such as a sprinkler in a building canopy, dry pendant heads may be used on a wet system. Heat trace tape is not permitted.

All new sprinkler systems shall have a central drain riser adjacent to the system riser, fully accessible to maintenance and safety personnel. With the exception of low-point and auxiliary drains, all new system drain risers shall be hard-piped to an approved exterior location or to a safe location in-side the building which shall accept full water flow without causing property damage or a safety hazard.

Project specifications shall include a requirement that inspector's test locations are determined to test the hydraulically most remote point in each system. These inspector's test drains shall also be piped as described above. Listed combination test/drain assemblies are permitted.

## A.2 Materials and Equipment:

The sprinkler pipe shall be schedule 40 black steel or galvanized, except for installations where nonferrous materials are required. Schedule 5, schedule 10, "light wall" designated, or plastic sprinkler pipe is not permitted.

Sprinkler system fittings shall meet the following requirements:

- Fittings into which sprinklers and sprinkler riser nipples are threaded shall be welded, threaded, or grooved-end type.
- Plain-end fittings with mechanical couplings and fittings that use steel gripping devices to bite into the pipe when pressure is applied are not permitted.
- Rubber-gasketed grooved-end pipe and fittings with mechanical couplings shall be permitted in pipe sizes 38 mm (1-1/2 in.) and larger.
- Fittings, mechanical couplings, and rubber gaskets shall be supplied by a single manufacturer per manufacturer's written instructions.
- Fittings shall be malleable iron, banded-type, or cast ferrous ductile iron with threaded ends or cut grooved with malleable iron or ductile iron fittings or standard seamless steel with butt-welded ends or forged steel with flanged ends.
- Copper tube shall be joined with brazed wrought copper fittings.
- Dielectric transitions shall be used as necessary in areas where ferrous piping cannot be used.
- Where pipe is galvanized, fittings shall also be galvanized.
- Where grooved joints are fabricated in galvanized or lined piping, only the cut-groove method is acceptable.

Where pendant sprinklers are installed on exposed piping (in areas with concrete ceilings), tee and elbows to which sprinklers are connected shall have one inch outlets and shall be

provided with 25 mm x 12 mm (1 in. x ½ in.) hexagon reducing bushings to permit connection of 25 mm (1 in.) drop nipples in the future.

Quick-response sprinklers are to be used throughout all NIH facilities, but standard-response sprinklers shall be used in autoclave areas, electrical switchgear rooms, transformer rooms, electrical closets, freezers, cold rooms, and mechanical rooms.

All FD connections shall be equipped with 62 mm (2-1/2 in.) National Standard Fire Hose Thread.

## A.3 Installation Requirements:

All concealed sprinkler piping and sprinkler piping in the stair-wells, storage rooms, mechanical rooms, and utility rooms shall be painted red enamel. All other exposed sprinkler piping (outside the stairwells) shall be painted to match the existing ceiling, and red enamel bands 100 mm (4 in.) wide shall be painted at 3,000 mm (10 ft) intervals. In aesthetically sensitive areas, exposed sprinkler piping shall be painted to match the existing ceiling without red enamel bands.

Sprinkler system isolation valves shall be located a minimum of 1,800 mm (72 in.) and a maximum of 2,300 mm (92 in.) above the floor. Where applicable, sprinkler system connections to the riser shall be positioned 90° apart from any standpipe connections sharing the same riser. Where system isolation and/or drain valves are located above “hard ceilings,” a 460 mm x 460 mm (18 in. x 18 in.) minimum access hatch shall be provided. When a dedicated fire protection service is provided, the isolation valve in the exterior water supply main shall be equipped with a lockable post indicator valve (PIV).

All sprinklers shall be installed 460 mm (18 in.) minimum from any air devices, as measured from the sprinkler to the side of the duct/device.

In areas with ceilings designed for water wash down, gasketed concealed sprinklers shall be pro-vided. In areas that also have a pressure differential at the ceiling, which can affect the operation characteristics of the concealed sprinklers, the gasketed concealed sprinklers shall be specifically listed for use in ceilings with pressure.

Sprinkler clearances to obstructions, including shelving, shall be in accordance with NFPA 13 spacing requirements. See Architecture Chapter 4 Section 4-2-10-B.5 “Joint Sealant and Caulking”: for shelving construction requirements. See Exhibit X9-2-A, Wall-Mounted and Peninsula Shelving Height Policy, for additional sprinkler clearance requirements.

All FD connections shall be equipped with a fixed weather-resistant information placard describing the type of system served and area of coverage. All system identification signs required by NFPA codes shall be provided and placement shall be coordinated with DFM and the appropriate maintenance organization.

## B. Fire Pumps:

Only electrically driven fire pumps shall be installed and shall be connected to an emergency power system, if available. See Electrical Chapter IX.B.6 “Emergency Power.” The fire pump shall be sized to provide the most hydraulically most demanding sprinkler system.

## C. Other Suppression Systems:

Antifreeze systems are not permitted. Pre-action suppression systems, as well as alternative agent suppression systems (water mist, halon replacements) shall be permitted on a per project basis to be coordinated with the Project Officer and DFM for selection and use.

A separate hydraulic calculation for the standpipe risers and bulk mains shall be provided to demonstrate that NFPA 14-required fire hose valve flows can be met from fire apparatus connected to the building’s FD connection. Assume a mobile fire apparatus supply of 131.5 L/s @ 1,379 kPa (35 gal/s @ 200 psi).

## D. Fire Hydrants:

A minimum of two hydrants shall be provided within 150 m (500 ft) of each building. All parts of the building exterior shall be reached by hose lays from at least one fire hydrant of not over 400 m (1312 ft), with consideration given to accessibility and obstructions.

Construction contract drawings shall show the locations of all hydrants that are intended to protect a new or renovated facility. Hydrant and standard thrust block details shall be provided.

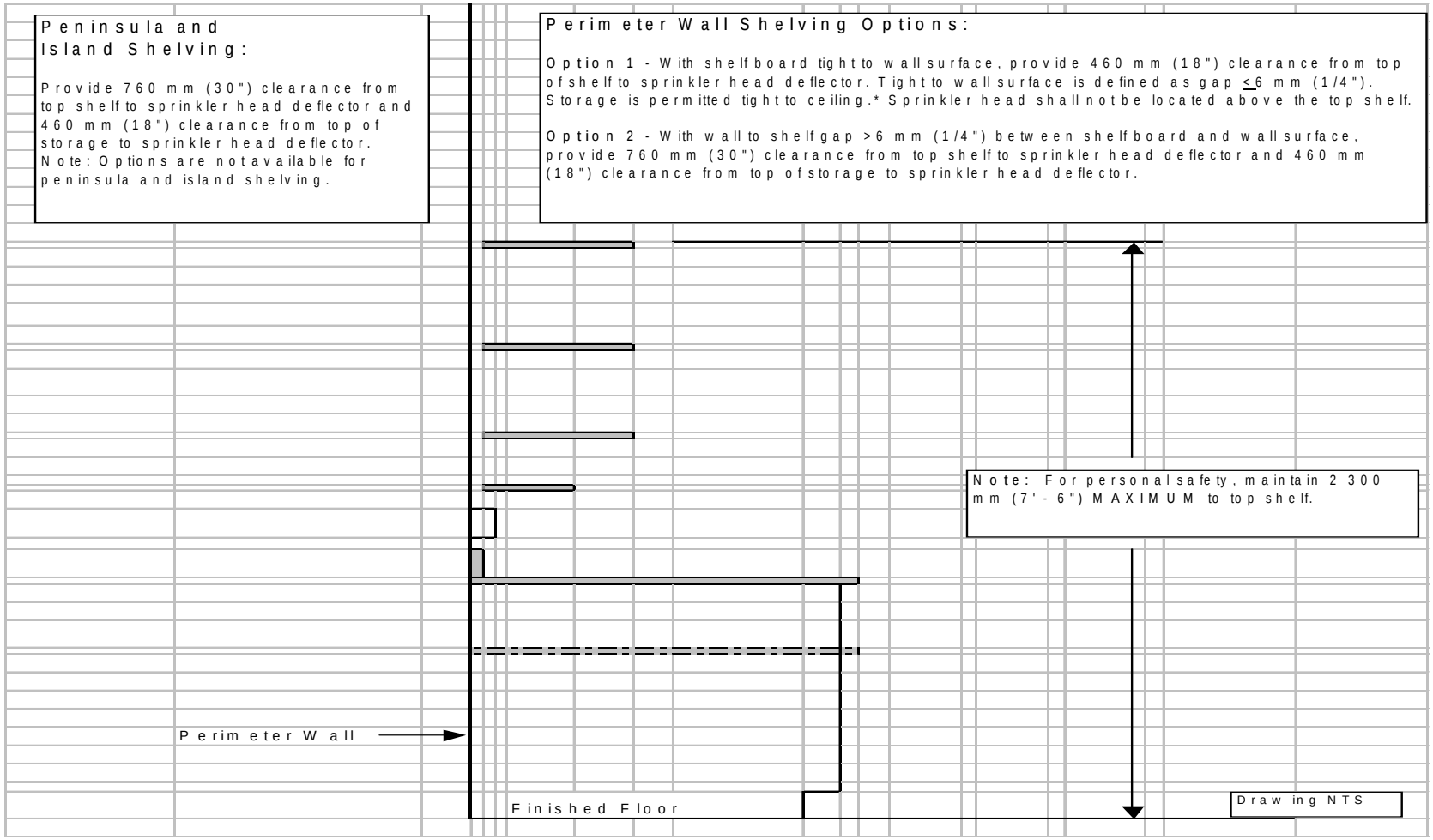
All fire hydrants shall be UL listed or Factory Mutual approved and shall be of the dry barrel type. The hydrants shall have two 62 mm (2-1/2 in.) hose outlets and one 114 mm (4-1/2 in.) pumper connection with National Standard Fire Hose Threads in accordance with NFPA 24, “Private Fire Service Mains and Their Appurtenances,” and NFPA 1963, “Screw Threads and Gaskets for Fire Hose Connections.”

All hydrants shall be installed adjacent to paved areas between 900 mm (36 in.) and 2 100 mm (83 in.) from the roadway shoulder or curb line, where they shall be readily accessible to FD apparatus.

All hydrants shall be located 12 m (40 ft) minimum away from the building they are intended to protect. Hydrants shall be installed with a 150 mm (6 in.) minimum connection to the supply main and shall be valved at the connection.

Roadway valves shall be located between 900 mm (36 in.) and 1,500 mm (60 in.) ( from the hydrant. The installation of all new hydrants shall conform to NFPA 24 except as modified above.

# Wall-Mounted and Peninsula Shelving Height Policy Sprinkler Head Clearance to Shelving




**Note: Per NFPA 13, the 460 mm (18 in.) dimension is not intended to limit the height of shelving on a wall or shelving against a wall. Where shelving is installed on a wall and not directly below sprinklers, the shelves, including storage thereon, may extend above the plane located 460 mm (18 in.) below ceiling sprinkler deflectors. Shelving, including storage thereon, directly below sprinklers may not extend above a plane located 460 mm (18 in.) below the ceiling sprinkler deflectors*

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# Section 9-3: Fire Protective Signaling Systems



## 9-3-00 Design Requirements

A fire alarm and evacuation system in compliance with the Federal Fire Safety Act of 1992 shall be provided for all new occupied facilities and/or additions greater than 185 $m^2$ (2,000 sq ft). Facilities smaller than 185 $m^2$ (2,000 sq ft) may be exempted, only with prior written approval of the NIH Fire Marshal.

Major renovations (e.g., of a wing or a floor) of a building with no fire alarm system shall include the provision of a fire alarm system in the renovated areas with provision of a control panel of suitable size to permit later expansion to other areas of the facility. All installations shall comply with the requirements of IBC, NFPA 101 LSC, NFPA 70, and NFPA 72 requirements.

Documents shall include system reprogramming, modification of graphic interfaces, and updating of system as-built drawings.

An addressable multiplex fire alarm system shall be provided in all new facilities. For the Bethesda campus, The addressable multiplex shall be capable of transmitting a coded signal over a positive shunt non-interfering campus-wide loop system. The transmitting of the coded signal shall be an integral function of the addressable multiplex panel without the use of additional systems or foreign equipment. All fire alarm codes associated with the building fire alarm system shall be acquired from DFM. See “Digital Addressable Fire Alarm System.”

Voice communication systems shall be provided with at least two audio channels. The audio channels shall be suitably supervised. Voice paging shall take priority over all automatic messages. The voice communication system shall be equipped with backup amplifier(s). The loss of any amplifier shall result in automatic switching to the backup amplifier(s). The

system's amplifier(s) shall be sized to accommodate the activation of all notification appliances. Adjustable volume levels for notification devices are required.

### A. Duct Smoke Detection:

Duct smoke detectors are not permitted in on-campus biomedical laboratory buildings and animal research facilities, except that duct smoke detectors are required in buildings or portions thereof which are Ambulatory Healthcare Occupancies as defined by the NFPA-101 Life Safety Code. All other applications are prohibited.

## 9-3-10 Design Guidance

### A. Design Parameters:

Fire protective signaling systems shall have the following circuit supervision styles per NFPA 72:

- All signaling line circuits (SLC) shall meet Style 6 requirements.
- All panel-to-panel communication SLC circuits shall meet Style 7 requirements.
- All initiating device circuits (IDC) shall meet Style D requirements.
- All notification appliance circuits (NAC) shall meet Style Z requirements.

If the main fire alarm control panel is required to have a backup control unit, the backup control unit shall be separated from the primary control unit by two hour fire-rated construction. Subordinate fire alarm panels are not typically required in fully sprinklered buildings.

General office areas are not to be equipped with smoke detection. Smoke detection shall be pro-vided below all raised floors with a depth of 460 mm (18 in.) or greater.

All laboratory corridors shall be equipped with approved smoke detectors if the constructed width of the corridor is greater than 1,500 mm (60 in.). In locations where sprinkler and standpipe connections share a common riser, fire alarm devices (e.g., water flow and tamper switches) shall be placed so as to minimize the possibility of draining operations spilling water onto the fire alarm devices.

The fire alarm field devices (initiating, notification appliance, and interface equipment) shall be shown on the electrical (power or dedicated electrical fire protection) floor plans. All field wiring shall be color-coded and reflected on the system as-built drawings, with the exception of addressable systems, but shall be labeled as fire alarm wiring.

All fire alarm control panels, remote data-gathering panels, power supply panels, and terminal cabinets shall be equipped with CAT 45 key and lockset.

Battery backup shall be provided on all fire alarm systems. Standby battery requirements shall include 72 hours of standby system supervision, and an additional 30 minutes with all notification appliances activated. In facilities served with an approved secondary power source or emergency generator-powered circuits, provide battery system for 24 hours of standby system supervision, and an additional 30 minutes with all notification appliances activated.

All fire alarm systems shall be equipped with a two minute time delay, such that all “trouble”, alarms are transmitted to the NIH FD between 120 and 200 seconds after onset of the trouble condition.

The A/E shall provide a fire alarm riser diagram on the electrical power contract drawings with the following information shown:

- All fire alarm-initiating devices (smoke detectors, heat detectors, manual pull stations, sprinkler water flow switches, control valve tamper switches, and any other supervisory devices).
- All fire alarm notification appliances (white strobes, red strobes, horns, speakers, and chimes).
- Existing fire alarm control panel; new fire alarm control panel and any remote panels; all conduit and wire (sizes and quantity).
- All interfacing devices (electric door strikes, door hold-open devices, auxiliary relays, and terminal cabinets).

## B. Fire-Protective Signaling Systems in Corridors:

In existing buildings where corridor storage is in place per NIH Corridor Utilization Policy, all laboratory corridors shall be equipped with approved smoke detectors if the constructed width of the corridor is greater than 1,500 mm (60 in.). Corridor storage shall not be permitted in new buildings, and smoke detection shall not be required in the corridors.

## C. Materials and Equipment:

All fire alarm wiring shall be installed in 19 mm (3/4 in.) minimum conduit or electrical metallic tubing (EMT). All fire alarm wiring in damp locations and in fire pump and valve rooms, at flow, and tamper switches shall be installed in liquid-tight flexible metal conduit and weather proof device boxes. Flexible metal conduit is limited to 1,800 mm (72 in.) and shall be secured per National Electrical Code. All fire alarm wiring installed underground shall comply with NFPA 70.

The suitability of notification appliances shall be evaluated on a case by case basis, and shall be as approved by the NIH DFM. All fire alarm system notification appliances shall be combination audible/visible appliances, with the exception of conference rooms, rest rooms and operating rooms, which shall be visible-only appliances. Supplementary audible/visible appliances shall visually match and be of the same manufacturer as combination audible/visible appliances. In areas with more than one strobe, the strobes shall be synchronized. In renovation projects, fire alarm notification appliances shall match existing equipment. Notification appliances shall not be installed in elevator cabs or stairwells. Special hazard areas, such as industrial shops, mechanical rooms, computer rooms, LAN rooms, power plants, and cage wash areas, shall be equipped with additional supplementary audible/visible appliances. High-voltage rooms shall be equipped with white strobes.

Animal area lighting control systems shall interface with the fire alarm system so that animal holding room lighting blinks during alarm, where required after consulting with DFM.

Heat detectors shall be combination fixed-temperature 57.2°C (135°F) and rate-of-rise units. High-temperature areas shall be equipped with appropriate high fixed-temperature heat detectors. Fixed-temperature 57.2°C (135°F) heat detectors shall be provided in areas subject to rapid temperature in-creases.

The fire alarm wire for 120 V AC circuits shall be #12 AWG, solid copper, TFN insulation.

Door holders shall be connected with #14 AWG, TFN insulation, solid copper at minimum.

Fire alarm wiring for low voltage circuits shall comply with manufacturer's written recommendations.

Fire alarm conductors shall be solid copper type. Strand wire is not permitted for new installations.

## D. Audible/Visible Notification Devices:

The standard notification sequence for the Bethesda Campus is a voice evacuation sequence. For other NIH installations covered by this document, the fire alarm notification appliance shall be in accordance with NFPA-72 National Fire Alarm Code and the International Building Code. In some cases, special alarm characteristics may be required for certain vivaria areas (typically off campus where voice actuation is not utilized). In such cases, the fire alarm notification devices shall be selected in accordance with NFPA-72 and the veterinary staff, and is subject to approval of the NIH DFM.

Facility devices that are subject to the elements or subject to wash-down (such as in interior areas of vivariums, cagewash etc.) shall be weather-proof. Fire alarms shall also alarm to high-containment biosafety personnel; reporting to any foreign system interface shall be through a supervised fire alarm relay. Red lens strobes shall be provided in animal holding rooms if required by the Program Area and shall be evaluated on a case-by-case basis by the NIH DFM.

## E. Installation Requirements:

New fire alarm control panels shall be installed in the building's main lobby/entrance, unless otherwise approved by DFM and the NIH FD, or when a fire command/control room is required by the IBC. If the fire protective signaling system includes an automatic smoke detection system, other than smoke detection required for elevator fire protection, then an addressable multiplex fire alarm sys-tem shall be provided. When an addressable multiplex fire alarm system is modified, the A/E's design shall be compatible with the existing components and systems.

All facilities have a hearing-impaired paging system compatible with existing pagers used in other Washington metropolitan area leased facilities. Coordinate all fire alarm paging codes associated with the building fire alarm system's hearing-impaired paging system with DFM. This requirement applies only to Bethesda Campus (except Poolesville and Frederick) and other metro Washington, D.C. lease facilities.

All special-purpose facilities that include animal facilities, high-rise buildings, windowless structures, tunnels, and vaults shall be equipped with an addressable multiplex fire alarm system, FD communication stations, and two-way occupant emergency communication. Upon an alarm, the speakers are to sound a "slow-whoop" signal, at 90 dB to 110 dB, for four cycles, followed by a voice evacuation message. Upon completion of the voice mes-

sage, the slow-whoop shall resound and continue until the fire alarm control panel is reset or the “alarm silence” switch is activated.

All testing of the system shall be performed in accordance with NFPA 72 requirements.

The location and accessibility of the fire command/control room shall be separated from the remainder of the building by not less than a one hour fire-resistance-rated fire barrier. The room shall be a minimum of 9 $m^2$ (100 $ft^{2)}$ with a minimum dimension of 2,440 mm (8 ft). Provide 1,525 mm (5 ft) clearance in front of all panels and clearance at the top, sides, and back of panels per written equipment manufacturer’s requirements. All IBC Fire Command Center requirements shall be provided with the following additional modifications:

- The room shall be located at or near the main lobby entrance approved by DFM, preferably on an outside wall, not located next to or adjacent to boiler, transformer, or hazardous locations.
- The room shall be provided with adequate ventilation necessary for removal of the heat generated by equipment.
- No electrical, mechanical, or plumbing equipment, other than directly related to the system, shall be located in or traverse the room, including the room’s ceiling plenum.
- The room shall be provided with phone and LAN connections.
- The room’s lighting and power outlets shall be on building emergency power with battery backup, where available.
- The room shall be provided with at least one emergency lighting fixture with self-testing battery ballast.
- The room shall be provided with at least one normal power and one generator powered receptacle.

For buildings with networked switchgear, the 120V power may be derived from the load side of the switchgear.

For buildings with non-networked switchgear, all 120V AC primary operating power for the fire alarm system shall be obtained from the line side of the building’s incoming power source ahead of all building services and disconnect switches. An independently fused safety switch with provisions for the cover and operating handle to be locked in the “power on” position shall be provided. This fused safety switch shall be located adjacent to the main electrical distribution panel. This enclosure shall be painted red and shall be labeled by a letter designation.

All concealed fire alarm conduits and fire alarm conduit in the stair-wells, storage rooms, mechanical rooms, and utility rooms shall be painted red enamel. All other exposed fire

alarm conduits (outside the stairwells) shall be painted to match the existing ceiling, and red enamel bands 100 mm wide shall be painted at 3 000 mm intervals. In aesthetically sensitive areas, exposed conduits may be painted to match the existing ceiling without red enamel bands subject to prior DFM approval. These painting requirements also apply to the pull boxes, junction boxes, mounting boxes, and extensions; however red enamel bands are not painted on such devices.

## 9-3-20 Design Information (Local Requirement)

### A. Bethesda Campus Mass Evacuation System:

The mass evacuation signal inputs shall be retransmitted simultaneously over all building fire alarm notification circuits and a separate notification zone from the building fire alarm panel, but shall not automatically activate with the building fire alarm system. Mass notification speakers shall be capable of delivering 4 watts, and provided as a weatherproof installation. speakers mounted 3,600 mm (12 ft) above grade and 12,200 mm (40 ft) on center.

# Section 9-4: Life Safety Features



## 9-4-00 Design Requirements

### A. Means of Egress:

The design of life safety features shall comply with NFPA 101 LSC requirements.

No loading dock exit door shall be utilized as a required egress path because they are subject to locking for security. Any such door shall be provided with a sign reading “NO EXIT.”

In new construction, delayed egress locks are not permitted, except that delayed egress arrangements in accordance with the IBC and NFPA-101 are acceptable with approval of the NIH DFM. Access control locks are permitted on a per project basis and shall be designed in accordance with NFPA 101 LSC. The A/E shall coordinate required system interfaces and use with the Project Officer and DFM.

### A.1 Minimum Means of Egress for Aisles:

A minimum 900 mm (36 in.) clear aisle space shall be maintained around laboratory benches and furniture.

### B. Emergency Power Requirements:

See Chapter 10 Electrical. The following systems that support life safety in a building shall be provided with an approved secondary power source:

- Exit signage.
- Exit lighting (exit access and exit).
- Fire protective signaling system (fire alarm system).

- Photo-luminescent exit sign light sources.

The following fire protection and life safety systems shall be connected to the available emergency generator-powered circuits:

- Exit signage.
- Exit lighting (exit access and exit).
- Fire protective signaling system (fire alarm system).
- Elevator(s) (operate one per bank and transferable).
- Smoke control system and/or stair pressurization (including controls and fans).
- Electric fire pump.
- Electric fire pump controller.
- Dry pipe sprinkler system air compressor/air maintenance device.
- Fire control room environment (power, lighting, HVAC).
- Elevator shunt trip power feeds.

## C. Fire Department Access:

All new buildings shall have at least two sides readily accessible to FD apparatus at all times. Access to all FD connections must be provided.

Fire lanes shall be provided for buildings that are set back more than 45 m (150 ft) from a public road or exceed 9,000 mm (30 ft) in height and are set back more than 15 m (50 ft) from a public road.

Fire lanes shall be 6,000 mm (20 ft) minimum width, with the road edge closest to the building at least 3,000 mm(10 ft) from the building. All fire lanes shall have curbs painted and appropriate signs provided.

The minimum roadway turning radius shall conform to the standard 15 m (50 ft) semi-trailer template.

Fire lanes shall be constructed of an all-weather driving surface capable of supporting imposed loads of 27,215 kg (60,000 lbs). Turf-filled paver blocks are not acceptable as an all-weather driving surface.

Any dead-end road longer than 90 m (300 ft) shall be provided with a turnaround at the closed end at least 27.5 m (90 ft) in diameter. Fire lanes and access areas for fire hydrants and automatic sprinkler/standpipe FD connections shall be clearly identified by painting ad-

jacent curbing yellow. In addition, signage shall be posted and spaced at 30 m (10 ft) intervals and/or at the beginning and end of the no-parking zones.

For roof access, every roof level of a building of two or more stories shall have at least one stairway access.

A FD-secured key box shall be provided in all new construction for emergency FD entry. The key box shall be located at the main entrance door of the facility. If any dimension of the building is more than 46 m (150 ft), then additional key boxes shall be remotely provided. The key shall match other existing secured key boxes.

## D. Fire Extinguishers:

Fire extinguishers shall have fully recessed cabinets, with the upper edge at 1,370 mm (54 in.) above the finished floor. All fire extinguisher cabinets shall be sized to contain a 9.6 L (2.5 gal) pressurized water extinguisher (Type 2). Fire extinguisher cabinet doors shall not have locks.

All laboratory fire extinguishers shall be located in the corridors. The maximum travel distance to an extinguisher shall be 15 m (50 ft).

## E. Self-Luminous Exit Signs:

Self-luminous or electroluminescent exit signs are a non-electrical product using radioactive tritium (H-3) gas to produce light. Tritium is regulated by the Nuclear Regulatory Commission as specified in 10 CFR 31.5. The installation of self-luminous exit signs is not permitted at the NIH on any construction project, including the temporary use for marking emergency egress. The removal, tampering, or disposal of any remaining existing self-luminous exit signs is strictly prohibited. Signs shall not be abandoned, relocated, transferred, or disposed of as construction debris.

Project specifications shall include a reporting requirement to immediately contact DRS (301) 496-5774 or 911, from an in-house campus phone, to report damaged or broken signs and to receive removal instructions and procedures.

# 9-4-10 Design Guidance

## A. Smoke Control Systems (IBC):

Smoke control systems, if provided or being renovated, shall have their method of operation and control mechanisms clearly defined in the "Fire Protection Engineering Analysis." Field control switches shall be provided, with locations coordinated with the NIH FD. The requirements for the design of atrium smoke exhaust systems shall be based on the International Building Code. If approved by the NIH Fire Marshal, equivalent methods of analysis utilizing the NFPA 92B *Guidelines for Smoke Management in Malls, Atria, and Large Areas* will be permitted. The equivalent analysis shall be documented in an engineering report and include an assessment of potential fuels, a fire dynamics analysis which may include fire modeling, and a tenability assessment for the period of occupant egress. In addition, the sequence of operations of all fire protection systems and HVAC interfaces shall be included.

## B. Smoke Barriers:

Smoke barriers shall only be required in accordance with the requirements of the NFPA 101 LSC. Protection of ducts and air transfer openings through fire rated construction shall only require a fusible link fire damper assembly. In cases of NFPA 101 LSC required smoke barriers or combination smoke/fire barriers, then ducts and transfer openings shall be protected by an appropriate smoke or combination fire/smoke damper.

## C. Fire Dampers:

Fire dampers shall not be provided on any fume hood system, in any laboratory fume removal exhaust system, or in laboratory hoods per NFPA 45. Alternative protection of the fire-rated assembly shall be provided by means of one of the following:

- Independent risers from each floor in a fire-rated shaft.
- Steel sub-ducts at least 560 mm (22 in.) in length shall be used at each branch duct connection of exhaust risers in which the airflow moves upward and the riser is appropriately sized to accommodate the flow resistance created by the sub-duct.

Penetration of Shaft Enclosures (Modification to IBC 716.5.3.1): Shaft enclosures that are permitted to be penetrated by ducts shall be protected by fusible link fire dampers. The use of combination fire/smoke dampers or smoke dampers is prohibited.

# Section 9-5: BSL3 & ABSL3 Biocontainment



## 9-5-00 Design Requirements

The design of the fire protection system shall be at the discretion of the A/E and shall comply with the current building and life safety codes listed in the reference section above and for the given jurisdiction. The system design shall meet the approval of the AHJ. Should the A/E pursue fire protection methods other than a conventional wet system, just cause and analysis is to be presented to NIH and AHJ. The system design shall be reviewed prior to approval by NIH and AHJ.

### A. Fire Protection Requirements for BSL-3 and ABSL-3 Containment Facilities

### A.1 General:

The requirements of this section apply to both BSL-3 and ABSL-3 laboratory and animal spaces, the term BSL-3 is utilized generically.

### A.2 Sprinkler Systems:

All BSL3 facilities shall be fully protected with an automatic sprinkler system.

### A.3 Containment Barrier Penetrations (General)

Penetration details for sprinkler piping shall meet requirements as described for plumbing penetrations through containment. Sprinkler pipe penetrations at the containment barrier of BSL3 facilities shall be detailed in the construction documents and shall require mock-ups to be constructed and tested prior to installation. Test criteria shall be that of the room tightness criteria and test as outlined by NIH. Mock-up, seal and room tightness test requirements for the sprinkler pipe and penetration shall be coordinated with other pipe and conduit penetrations and layout and shall meet the same standards as outlined in Chapter 8 “Plumbing”.

### A.4 Containment Barrier Fire Sprinkler Penetrations BSL-3:

Sprinkler heads shall be pendant type and shall not be recessed or concealed. The piping drop shall extend through the penetration sufficient to allow for application of a visible seal. Escutcheons shall not be provided, however a flat solid stainless steel plate or washer that is tight fitting against the pipe may be utilized bedded in sealant and sealed to the pipe circumference. Piping drops shall be rigidly braced to structure prior to penetrating the containment barrier to preclude damage to the barrier seal due to piping movement that can occur during events such as system maintenance or impact. Sealant application shall be provided so as to not adversely affect the operation or UL listing requirements of the sprinkler head. Sprinkler head and pipe material and finish shall be resistant to chemicals used during the daily operation of the laboratory and decontamination procedures.

### A.5 Fire Protective Signaling Systems:

BSL-3 laboratories shall receive standard notification appliances, to include combination appliances and speakers. Fire sprinkler and alarm zones should be coordinated and shall be as approved by the DFM.

## 9-5-20 Design Information

The A/E shall refer to Sections 2-5 and 2-6 in Chapter 2 and the preceding sections of this chapter and make a determination of all applicable provisions that are to be incorporated into the design of the biocontainment facility.

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# Electrical

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# Section 10-1: Electrical Design Considerations



## 10-1-00 Design Requirements

The following design requirements apply to all electrical systems. The goals and objectives are to provide uniformity of design; combine the best overall economy with suitability of design; and be compatible with all other building systems. Provision shall be made for the addition of future electrical loads as determined by the NIH on a project-by-project basis.

## 10-1-10 Design Guidance

### A. Design

Where the electrical design is of an unusual nature and the intent is not readily discernible, the basis of design and/or design analysis narrative shall be prepared to explain the intent and reasoning behind the innovative design. This shall be presented in the earliest stage of review to ensure that the design is suitable.

## 10-1-20 Design Information

### A. Reference Design and Safety Guidelines for the Electrical Designer:

The NIH is a progressive and dynamic biomedical research institution where state-of-the-art medical research is the standard practice. To support state-of-the-art research and medical care, the facilities must also be state-of-the-art. It is NIH's intent to build and maintain the electrical systems and facilities in accordance with the latest standards.

It has been the NIH experience that the renovation and rehabilitation of existing facilities do not always lend themselves to incorporating the "latest" standards of the industry. Some of the existing electrical systems are outdated or inadequate for the new load. Often the planned function is incompatible with the original criteria for the building.

The A/E should be alerted to this situation and make an evaluation early in the design stage to determine the implementation feasibility of the latest standards. The A/E should document such findings, provide recommendations, and report them to the Project Officer for a decision on how to proceed.

The A/E design firm should use and comply with, as a minimum, the latest issue of the following design and safety guidelines available at the time the project proceeds with schematic design. In addition, the A/E should use other safety guidelines received from the NIH Project Officer or as required by the program.

The reference codes, regulations, and recommended practices include but are not limited to the latest version of the following:

- Association of Edison Illuminating Companies (AEIC)
- American Hospital Association (AHA), Management and Compliance Series, Electrical Systems for Health Care Facilities
- American National Standards Institute (ANSI)
- AHA, Management and Compliance Series, Fire Warning and Safety Systems
- American Society of Mechanical Engineers (ASME) A17.1: Safety Code for Elevators and Escalators
- Electronic Industries Alliance (EIA)
- International Building Code (IBC), International Code Council, Inc.
- International Cable Engineers Association (ICEA)
- International Electro-technical Commission (IEC)
- Institute of Electrical and Electronics Engineers (IEEE), Color Books
- Illuminating Engineering Society of North America (IESNA), Lighting Handbook
- Lightning Protection Institute, LPI 175 Standard of Practice
- National Electrical Code (NEC), National Fire Protection Association NFPA Standard 70
- National Electrical Manufacturers Association (NEMA)
- National Electrical Safety Code (NESC) IEEE C2
- International Electrical Testing Association (NETA), Acceptance Testing Specifications for Electric Power Distribution Equipment and Systems
- NFPA, National Fire Codes (NFC)
- NIH, Design Requirements Manual
- Institute of Laboratory Animal Resources (ILAR), The Guide for the Care and Use of Laboratory Animals
- Telecommunications Industries Association (TIA)
- Uniform Federal Accessibility Standards (UFAS)
- Underwriters Laboratories (UL)

# 10-1-30 Design Document Requirements

See Appendix B for detailed requirements of submittals at each phase of the project.

## A. Electrical (Schematic, Design Development and Contract Documents)

Lighting and Power floor plans, one line diagrams, fixture, panel and equipment schedules, miscellaneous details, and cover sheet requirements.

## B. Specifications (Outline and Detailed Performance Specifications)

Outline specifications shall be developed at the design development stage and detail performance specifications shall be developed at the contract document stage.

## C. Cost Estimates (Systems and Quantity Takeoff Estimates)

Systems cost estimates shall be developed at design development stage and quantity takeoff estimates shall be developed at the contract document stage.

## D. Calculations and Analyses:

Each electrical design shall include the submittal of the following design calculations and analyses:

- Lighting calculations providing illumination levels in lux. Point by Point calculations shall be provided for areas with unique lighting arrangements.
- Estimated connected and demand distribution equipment loading, including an additional 25% for future building loads.
- Electrical service sizing based on the NEC and the DRM.
- Panelboard loads summation for justification of distribution equipment sizing.
- Economic analysis for justification of selection of either 120/208 V or 277/480 V on the secondary side of the network distribution transformers.
- Analysis to determine, if large central or smaller 120/208 V step-down transformers are to be used. An economic analysis shall be performed if the choice is not obvious.
- Transformers, Uninterruptible Power Supply (UPS) and Generator sizing calculations.
- Voltage drop calculations for branch circuits longer than 20 m (65 ft.) at 120V and branch circuits and feeders longer than 45.7 m (150 ft.) at 277V or higher.
- Initial short circuit analysis determining the interrupting or withstand rating of the system components and justification for selection of distribution equipment. Final short circuit analysis shall be performed by the distribution equipment manufacturer based on the actual distribution equipment proposed for installation.
- Coordination study determining the circuit breaker settings and system coordination. Final coordination study shall be provided by the distribution equipment manufacturer.

The A/E shall provide hard copy reports and all electronic files associated with the power system study showing corresponding bus and cable run identification numbers corresponding to the calculations; system load calculations for switchgears, switchboards, motor control centers (MCCs), panelboards, busways, risers, and transformers; and product and photometric data sheets for all fixtures specified in the design.

The power system study shall be performed using NIH approved software and shall be submitted to the Project Officer prior to receiving final approval of the distribution equipment shop drawings and/or prior to release of equipment for manufacturing. If formal completion of the study would cause delay in equipment manufacturing, approval from the Project Officer may be obtained for a preliminary submittal of sufficient study data to ensure that the selection of device ratings and characteristics will be satisfactory.

The study shall include executive summary, assumptions; short circuit study results, load flow study results, motor starting study results, protective device coordination results, feeder voltage drop calculations, arc flash analysis and conclusions. The study shall include all portions of the electrical distribution system from all power source(s) including the smallest adjustable trip circuit breaker in the distribution system. System connections that result in maximum fault conditions shall be adequately covered in the study.

The study shall be performed, stamped, and signed by a registered professional engineer, with a minimum of five years of experience in power system analysis. Credentials of the firm/individuals shall be submitted to the Project Officer for approval prior to start of the work.

## E. Panel Schedules:

Panel schedules shall be completed on construction drawings, including all data required to order the equipment and to identify the attached loads. Information shown shall include:

- Panel name.
- Number and size of all breakers, including spares.
- Number of bussed spaces and the maximum ampere frame ratings.
- Total number of breaker positions in the panel.
- Bussing ampacity.
- Main circuit breaker (MCB) and rating or main lugs only (MLO).
- Surface or recessed mounting.
- Top or Bottom Feed.
- Installed location of panel.

- Trip rating, frame rating, and number of poles of each breaker.
- Short circuit interrupting rating of the panel; series rating not acceptable.
- Identification of the load and room number.
- Estimated connected load in volt-amperes (or kVa) per circuit (in watts or kW for generator loads).
- Panel total connected kVa and amperes (in watts or kW for generator loads).
- Panel total demand kVa and amperes (in watts or kW for generator loads).

## F. Testing and Operational Requirements:

The A/E shall incorporate the following in the project specifications:

- Testing and operational training requirements.
- Startup and checkout of building systems.
- Operation and maintenance (O&M) manuals for all electrical equipment supplied on the project, in both hard copy and electronic formats on a CD-ROM, DVD, etc. Scanned items are acceptable.

## G. Lighting Schedule

A lighting fixture schedule on drawings, identifying at least three manufacturers, catalog numbers, fixture voltage, lamp types, number of lamps, fixture depths, installation methods, description of fixtures, and remarks shall be provided for each fixture type identified as approved equals

# Section 10-2: Site Electrical



## 10-2-00 Design Requirements

### A. New Service Connection:

The NIH shall determine the most appropriate location for a service connection to the medium voltage (13.8 kV) system on the NIH Bethesda campus. The service may require a new feeder from the nearest 15 kV substation. The A/E shall contact the Project Officer for coordination with the NIH high voltage supervisor for more detailed information specific to the project.

All secondary substations at the NIH Bethesda campus shall be spot network type where the anticipated load is over 500 kilovolt-amperes (kVa). If redundancy is required at facilities other than on the NIH Bethesda campus, a double ended, secondary selective system may be considered after approval from the Project Officer. The secondary selective system, if used, shall consist of two primary feeders, two fused load interrupter switches, two transformers, two secondary main breakers, and one tie breaker, plus the necessary feeder breakers. Secondary selective systems shall be provided with automatic transfer.

All transformers, secondary substation and distribution gear, generators and transfer switches shall not be located in the lowest points of the buildings below grade level to avoid possible flooding.

### B. Standard Cable Size and Type:

The NIH standard is 500 thousand circular mils (KCMIL) and 350 KCMIL as the only acceptable sizes for the 15 kV copper cable. The system voltage is a nominal 13.8 kV, and the NIH system is operated ungrounded. The typical existing cable is paper-insulated lead-covered (PILC) cable, compact-sector, 100% insulation, and shielded with the lead sheath grounded in each manhole. Splices shall be custom made at each site by an experienced cable splicer using customized splicing kits from a reputable cable manufacturer. All splices shall be started and carried through to completion without interruption. Only PILC cable shall be spliced to PILC cable.

All new feeders installed from a 15kV substation shall be ethylene-propylene rubber (EPR). EPR cable shall be 500 KCMIL, 15 kV single copper conductor, shielded 105°C and rated with a 133% insulation level. The strand screen shall be extruded semiconducting EPR meeting or exceeding the electrical and physical requirements of ICEA S-68-639, AEIC CS8, and UL 1072. The shield shall be 5 mil thick bare copper tape helically applied with a 12.5% overlap. The jacket shall be a polyvinyl chloride (PVC) jacket. The cable shall be UL listed as Type MV-105 in accordance with UL 1072. Each feeder shall consist of three single conductor cables, plus a ground wire as described hereinafter, or a three conductor cable with an integral ground.

## C. Distribution Duct System (DDS):

For new manholes, the surrounding grass areas shall be graded to drain away from the manhole cover. Manhole covers shall be 15 mm (0.5 in.) above finish grade. Preference of manhole location is as follows: grass areas first, sidewalks second, and in the street last. Manholes shall not be located in parking spaces. Where ducts are sloped from a high to a low manhole, they shall be sealed at the high end only to allow condensation to drain.

Distribution duct bank conduits shall be a minimum of 4-way, 129 mm (5 in.). A #4/0 ground conductor shall be provided in all new medium voltage ductbanks.

## D. Elevation Considerations:

The spacing between ducts shall be 75 mm (3 in.) in all directions. The ducts shall be 760 mm (30 in.) minimum clear below grade or from the top of roadway and completely below the frost line.

Duct runs shall be sloped from the higher manhole entrance to the lower manhole entrance with no intermediate low spots that pool moisture. If manhole entrance points are on about the same level, an arch in the duct run is required so that there is drainage from a high point into both manholes. If a low point is absolutely unavoidable, another manhole shall be provided at or near the low point. Ducts entering a building shall be sloped toward a manhole to ensure positive drainage away from the building.

## E. Manholes and Handholes:

The minimum inside dimensions of manholes shall be 3700 mm x 2750 mm x 1980 mm (12 ft. x 9 ft. x 6.5 ft.). Handholes shall be a minimum 610 mm x 610 mm x 610 mm (2 ft. x 2 ft. x 2 ft.) and shall have grounded steel covers. Manholes shall be provided with a sump approximately 300 mm x 300 mm x 150 mm (12 in. x 12 in. x 6 in) deep. The sump should be directly in line with the manhole cover so that a pump can be lowered into the sump without entering the manhole. Cables in manholes shall be labeled with embossed brass cable tags

and brass chains. Manholes shall be provided with two manhole covers, one for forced air and materials entry and the other for worker access. The standard manhole frame and cover shall be 700 mm (2.25 ft.) in diameter (600 mm (2 ft.) inside diameter). Manhole covers shall be labeled "ELECTRIC" for power and "COMMUNICATIONS" for communications. The cover shall have a small, flat area for labeling, with the manhole number applied by a welded bead. An embossed brass tag with the manhole number shall be permanently mounted inside the manhole collar and legible from outside the manhole with the cover removed.

Handholes shall not be used on medium-voltage power systems. All cables shall be racked on nonmetallic cable racks designed for installation on walls of manholes. Handholes and manholes in streets, immediately adjacent to and within 5 m (16 ft.) of a street shall meet state Department of transportation standards.

## F. Manhole Grounding:

Each manhole shall be equipped with a 3 m (10 ft. ) long, 19 mm (0.75 in.) diameter copper-clad steel ground rod through the floor of the manhole, with all metallic components in the manhole, such as racks, cable sheaths, and ladder, securely grounded to this rod with a #6 AWG green insulated cable.

## G. Maximum Length between Manholes:

The maximum cable length between manholes shall be less than 120 m (400 ft.) for an essentially straight run and reduced by 15 m (50 ft.) for each bend of 0.79 radians (45 deg.); and by 30 m (100 ft.) for each bend of 1.6 radians (90 deg.). Bends shall be made with the largest radius possible. The A/E and the contractor shall perform the necessary cable-pulling calculations to ensure that the maximum tension or sidewall pressures are not exceeded.

## H. Spare Capacity:

When new duct runs and manholes are installed, additional ducts shall be provided for future expansion. There shall be at least two spare ducts included with the required ducts; or more if this shall round out a duct bank to a symmetrical configuration. Odd numbers of duct, such as 7, 11, or 13, shall not be constructed. All empty ducts shall be sealed to prevent water seepage into the handhole or manhole. All ducts shall be shown in section, identifying and labeling used ducts and spare ducts.

## 10-2-20 Design Information

### A. Distribution Duct System (DDS):

The NIH Bethesda campus has two underground duct and manhole systems: one for electrical power cables and one for communication circuits. The DDS for electrical power has manholes designated with the letter “E” followed by a number (one to three digits). Where a duct line branches off an existing manhole, the new manhole shall have a sub-letter designation. For example if the existing manhole is E-29, two new manholes added on the same branch would be named E-29A and E-29B.

The ducts contain only medium-voltage feeders, rated 15 kV for use on the NIH nominal 13.8 kV system, and supervisory cables that monitor and control the medium-voltage system. The older supervisory cables are multi-conductor control cables, presently being replaced with smaller diameter data links over fiber-optic paths in the existing campus local area network (LAN) cables and over telephone lines.

The DDS consists of multiple duct runs between manholes of 129 mm (5 in.) inside diameter PVC Schedule 40 ducts with a concrete encasement. The encasement has steel reinforcement in a plane just below the lowest row of ducts where the duct run spans disturbed earth, where it enters manholes and buildings (out to 1.8 m (6 ft.)), and where it crosses under heavily traveled roadways.

## 10-2-30 Design Document Requirements

On electrical site work related drawings all new manholes shall be documented with expanded views identifying each face and bottom. All duct penetrations shall be identified and labeled, including spares.

# Section 10-3: Normal Power

10-3- 00 Design Requirements
10 Design Guidance
20 Design Information (Reserved)
30 Design Document Requirements

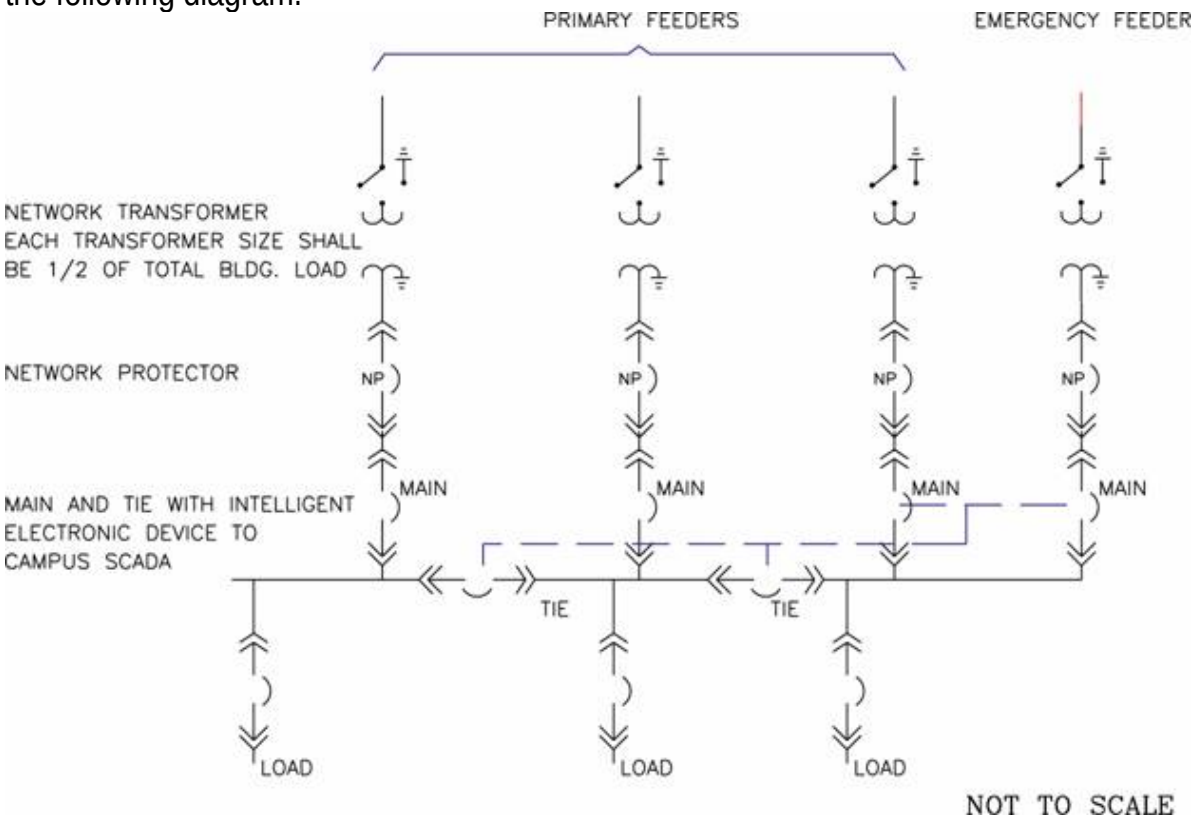
## 10-3-10 Design Requirements

### A. Electric Service

The requirements for building electric service for campuses other than Bethesda shall be coordinated with the facilities operations associated with the campus.

### B. Network Transformers and Spot Network Equipment:

The typical building service in the Bethesda Campus shall utilize a three transformer spot network. Some older installations may include an emergency feeder. Each transformer shall be sized for 50% of the total building load, including any spare or future capacity. See the following diagram.




Single Line Diagram: Typical Building Service

Limit main and tie circuit breakers and busing to 4000 A or less in any spot network configuration.

The spot network configuration shall be sized to allow one network transformer to be removed from service, with the remaining spot network transformers capable of carrying the entire load indefinitely without transformer fan-forced cooling, plus an additional 25% spare capacity designated for future modifications to the electrical power distribution system.

Each secondary spot network shall include a 3-position primary 15 kV switch, network transformer, a secondary network protector and no-load break isolation switch. Project specifications shall require the manufacturer of the spot network substation shall furnish and coordinate all major components of the substations, including: incoming primary equipment section; network transformers; low-voltage network protector; no-load break isolation switch; control devices; protective relays; metering components; provide components for remote monitoring and control of all main circuit breakers, tie circuit breaker and selected feeder circuit breakers as determined by NIH campus Supervisory Control and Data Acquisition (SCADA) system and a single warranty covering all substation assemblies, transformers, and components. The spot network substation shall be designed, assembled, tested, and installed in accordance with the latest applicable standards of NEMA, IEEE, and ANSI applicable to network transformers and network protectors.

Spot networks shall include a remote terminal unit (RTU), a multiplexing device sending monitoring and control signals from the respective building to the campus-wide SCADA.

The RTU shall be located in either the transformer vault or the secondary switchgear room and shall require a 120 V circuit. The output control voltage is 48 V DC. The network protectors shall have auxiliary relays with 48 V DC coils for shunt tripping by the RTU. The RTU shall include monitoring the following devices/functions:

- Pressure and temperature of liquid-cooled network transformers.
- Status of network protectors.
- Status of all secondary main and tie circuit breakers.
- Status of any battery bank systems in substations.

The RTU shall include controlling the following devices:

- Tripping of network protectors.
- Opening and closing of secondary main and tie breakers.

The RTU shall include analog inputs to measure all secondary switchgear metering. The RTU is provided with a number of analog and digital sensing points, as well as a number of relays for the control functions, and the number of points shall be augmented in the future as additional points are needed or defined.

Buildings fed from single pad mounted transformers in lieu of the spot network system shall be provided with monitoring via the campus wide SCADA system and provided with electronic main circuit breakers.

## C. Primary Switch:

The 15 kV primary switch is a three-position, no-load break switch. The three positions are OPEN, CLOSED, and GROUND. The closed position is the center position. The switch is key interlocked, with the transformer tap changer mechanism, such that it shall be in the ground position before the transformer taps can be changed.

## D. Network Transformer:

Transformers shall have temperature gauges with re-settable maximum pointers, sampling valves, high-pressure release valves, and a key-interlocked tap changer. The transformers shall be filled with an NIH approved less flammable natural ester liquid. The tap changer shall have five settings, two above and two below the 100% rating. Each tap shall represent 2.5% of nominal voltage. Transformer windings shall be copper and full kVa rated.

## E. Network Protector and Relays:

The network protector shall be a maximum-rated device, by an NIH approved manufacturer and compatible with NIH systems. The network protector shall be a fully interlocked, dead-front, draw-out design with externally mounted fuses for easy removal of the unit from enclosure for maintenance and inspection by operating hand-cranked levering system. Relay and control panels shall be mounted on draw-out control module below network protector element. Protectors shall be UL listed and comply with the IEEE C57.12.44 standard. The network protector shall have a mechanism controlled by a toggle cam device that shall not allow closure of the contacts until the springs contain sufficient energy to close and latch the contacts onto available fault current. Each network protector shall have a disconnect switch mounted on top of or on the opposite wall from the network protector. The disconnect is a maintenance isolation switch for working on the network protector. Disconnecting links are not permitted for safety reasons.

The network protector shall contain time delays and other controls to prevent “pumping,” defined as the cyclical opening and closing of the network protector.

Each network protector shall have a communicating discrete network intelligent electronic device (IED) with terminals located outside the gear. The IED shall be a three-phase type with relay functions to provide selective closing and tripping of auxiliary contacts mounted on the relay and interfaced with the protector circuitry. The relay close contact shall close if the ensuing positive sequence power will be into the network. The relay trip contact shall close when there exists a net three-phase reverse power flow through the network protector. The trip contact shall also close upon flow of reverse magnetizing current of its associated transformer.

The relay shall be enclosed in a NEMA Type 6 chemically treated, waterproof drawn brass shell, and any wiring to the relay (including communication cable) shall not compromise the rating. The relay shall offer three on-board input ports that are used for external sensors when combined with the communication package; offer internal air temperature with the communication package; utilize the capability of choosing from the traditional straight-line master close curve and the modified circular closed curve; and utilize insensitive phase rotation.

The microprocessor relay shall operate under the sequence-base algorithm, which provides a flat, unchanging trip response. The relay shall have the capability to communicate information to a data concentrator over a shielded twisted pair communications cable.

## F. Secondary Switchgear:

Secondary low-voltage switchgear shall be the freestanding, ANSI metal enclosed draw-out type. The switchgear shall have a main circuit breaker on the secondary of each unit substation transformer. All circuit breakers shall be electrically operated air power circuit breakers or vacuum circuit breakers. Circuit breaker selection shall accommodate the inherently high available short circuit interrupting current in a spot network system arrangement. Spare cubicles with circuit breakers shall be provided with a minimum of one cubicle per frame size utilized in the switchgear lineup. All spaces shall be fully bused based on frame sizes which shall be indicated on design drawings, including draw-out assemblies, bused connections, and hardware. All bus stubs shall have insulated covers. If transient voltage surge suppression (TVSS) is required on switchgear, it shall be modular type and provided in the switchgear. Molded case circuit breakers shall not be permitted in switchgear construction except breakers for TVSS provided with appropriate short circuit interrupting rating. All cubicles shall be complete with bus work, rails, wiring, equipment shorting blocks and circuit breakers. All buses shall be copper with plating per manufacturer. The switchgear shall be positioned to allow for the addition of a minimum of one vertical section to the switchgear, provided that switchgear capacity is not exceeded.

The electrical arrangement of the switchgear is shown in single-line form in the beginning of this section. Each main circuit breaker shall serve a section of the main bus. The sections shall be connected by tie breakers of the same ratings as the mains. The main and tie breakers are normally closed and electrically operated. The normally closed breakers form a spot network. The tie breakers shall sectionalize the main bus should a fault occur, minimizing the outage to one section of bus. The breakers shall be electrically operated to allow remote operation by the campus SCADA system.

Switchgear main and tie breakers shall have discrete contacts for open close status wired to terminal strips for convenient access for SCADA connection. Switchgear shall have all potential transformer (PT) and current transformer (CT) connections wired out to shorting blocks. Switchgear IEDs shall be equipped and wired to test switches which shall allow ease of troubleshooting and repair/replacement of IEDs when necessary.

For a spot network system, a unique dual ground bus arrangement is required for proper selective ground fault operation and isolation of a fault. Where ground fault protection is required on main circuit breakers, it shall also be provided on feeder circuit breakers to provide selective tripping of the breaker closest to the fault. Ground fault protection shall be provided on all circuit breakers serving 480/277 V, 3 phase, 4 wire bus risers, switchboards and distribution panels which could possibly serve fluorescent lighting.

The control power for low-voltage circuit breakers shall be 120V AC. Overcurrent devices shall have short-time, long-time, ground fault, and instantaneous trip settings. Each incoming line shall be provided with over voltage and under voltage, and phase sequence protection.

The switchgear shall be provided with a digital power meter measuring total power output of the switchgear. Digital readout metering shall be provided on the load side of each main circuit breaker with required metering:

- Volts (phase-to-phase and phase-to-neutral).
- Frequency.
- Ampere demand (per phase and average three-phase).
- Kilowatt hours (resettable).
- Kilowatt demand (three-phase).
- kVa demand (three-phase).
- Harmonic load content (percent total harmonic distortion (THD)).

- Power factor.

The switchgear shall include the provision of a control power transformer associated with each switchgear section and the necessary switching logic so that there shall be 120 V relay and control power if any one of the three network transformers is energized.

Each feeder breaker shall have self-contained local digital metering with remote reporting capability. In addition to the required SCADA metering, monitoring, and control system, the following values shall be metered:

- Volts (phase-to-phase and phase-to-neutral).
- Amperes.
- Kilowatt hours (with reset).
- Kilowatt demand.
- Kilowatt peak demand.

Each switchgear lineup shall have a hoist provided for lifting the circuit breakers from their withdrawn position and lowering them to a dolly or to the floor. A rail assembly shall be provided along the top of the switchgear with a hoist mechanism that can roll from end to end.

Switchgears shall be located in dedicated electrical rooms. Piping, ducts, or equipment not serving the electrical equipment shall not be permitted to be installed in or traverse dedicated electrical rooms.

Electrical strip heaters shall be installed in switchgear to prevent internal condensation.

All specialized tools necessary for installation, maintenance, calibration, or testing of electrical equipment supplied with the associated equipment shall be turned over to the Government at the end of the construction project.

## G. Distribution Transformers:

Distribution transformers shall be delta primary with solidly grounded wye connected secondary. The transformer shall have self-cooled capacity for 100% load plus 25% spare capacity for future loads. Liquid-filled transformers shall be filled with an NIH approved less-flammable natural ester. Liquid-filled transformers shall be provided with liquid level, pressure/vacuum, and temperature gauges with alarm contacts. The transformer shall have five taps, two above and two below the 100% rating. Each tap shall represent 2.5% of nominal voltage.

## H. Busway:

Busway shall have all copper bus; maximum ampacity for one busway riser shall be limited to 2,000 A. Aluminum busway shall not be used. Ventilated busway shall be installed in dry locations. Non-ventilated busway shall be installed in wet or moist locations. Project specification shall hold the contractor liable for field measuring for the busway prior to ordering. 100 mm (4 in.) high concrete curbs shall be provided at all vertical busway penetrations. Busways shall be installed such that there is adequate code required clearance for existing and future plug-in devices.

## I. Work Space:

All projects shall provide the minimum required clearances per code for all equipment; and the following minimum clearances are required on new projects around secondary switchgear:

- 1,500 mm (5 ft.) in front.
- 1,100 mm (3.5 ft.) in rear.
- 900 mm (3 ft.) on the ends.

The electrical equipment in electrical rooms and closets shall be laid out such that a 900 mm (3 ft.) wide, unobstructed path to the exit door shall be available.

All substations, switchboards, transformers, network protectors and distribution panelboards shall be installed in dedicated electrical rooms or closets, or if outdoors, in areas protected against physical and water damage. Provide house keeping pad for all floor mounted equipment.

At least one duplex receptacle and 25% of the lighting fixtures in electrical rooms, electrical closets, communication rooms, communications closets, and mechanical rooms shall be connected to emergency power, if available. Each electrical room and closet shall be provided with at least one receptacle. Each communications room and closet shall be provided with a minimum of two receptacles. A finished ceiling is not required. Electrical and communication rooms and closets shall be centrally located to loads served.

## I.1 Electrical Rooms:

In addition to required clearances, adequate space shall be provided for the installation and removal of equipment without requiring disconnection of any other equipment except that which is specifically connected to the piece of equipment to be removed. Columns shall not encroach on clear space required around equipment.

## I.2 Electrical Closets:

Electrical closets shall be minimum 1.5 m x 2.4 m (5 ft. x 8 ft.) for closets without transformers and minimum 1.8 m x 3.0 m (6 ft. x 10 ft.) for closets with transformers. Closets with transformers shall have ventilation (and/or cooling) sufficient for 2% of the total transformer kVa expressed in watts of heat load. Electrical panelboards shall be located so that the farthest 120 V device served is within a 20 m (65 ft.) radius of the closet, and electrical closets shall generally be placed one for every 930 sq. m (10,000 sq. ft.) of area served by 208/120 V branch-circuit panelboards. Loads served with 277 V shall be no more than a 30 m (100 ft.) radius from the closet, and lighting panels shall be placed approximately one every 1860 sq. m (20,000 sq. ft.). Building configuration shall dictate the number of closets, but the 20 m (65 ft.) rule shall be maintained to minimize increasing branch circuit wire size for voltage drop reasons.

Shallow closets with full doors on the long wall are acceptable in lieu of electrical closets for smaller renovations. Panelboards are not required in closets and may be located in secure service corridors. Electrical closets in multistory buildings shall be stacked. Closets shall not be located adjacent to mechanical shafts and shall be coordinated with all other building systems, particularly those located in the ceiling plenum directly adjacent to the closet.

Two lamp fixtures shall be provided to meet the light level requirements. Refer to Paragraph B.8.e “Interior Lighting.”

The A/E shall not obtain new circuits from panelboards in remote areas or other floors of the building. Holes in floors of electrical closets shall be provided with sealed watertight sleeves extending at least 70 mm (3 in.) above the floor.

## J. Switchboards and Panelboards:

Switchboards and Panelboards shall be fully rated. Series rating is not acceptable. Circuit breakers shall be the bolt-on type. Plug-in breakers shall not be used. The breaker shall have a published ampere interrupting rating at 125/250 V DC. For purposes of this requirement, it shall be assumed that a DC rating for one-pole and two-pole breakers extends to the three-pole device as well.

Every switchboard and panelboard shall have a main circuit breaker (MCB) in the same enclosure if a local disconnecting means is not in the same closet or room. Single pole breakers shall not be ganged to form multi-pole breakers. Circuit breakers serving exterior lighting shall be Ground Fault Circuit Interrupting (GFCI) type.

The switchboard and panelboard directories shall be typed and shall reference the actual loads and room numbers for the circuits. Project specifications shall hold the contractor liable for accurate directory referencing regardless of room numbers used on contract documents. The directory shall list the switchboard or panelboard name and the name of the source panel.

New switchboards and panelboards shall allow for 25% future spare load capacity. New switchboard and panelboards shall contain 25% spare circuit breakers upon completion of construction. The spare breakers shall be left in the "OFF" position, and the panelboard directory card shall list the word "SPARE" on each line for these breakers. New switchboards and panelboards shall contain space for future circuits that amount to at least 25% of those required in the initial design.

Operating rooms associated with ABSL facilities shall have isolated power panels with ungrounded secondary and line isolation monitors.

Distribution panels shall be defined as those panels serving branch circuit panelboards and other three phase loads. Distribution panelboards shall be located in electrical rooms or closets provided with code required clearances and 76 mm (3 in.) minimum separation. Branch circuit panelboards may be located within the area being served, if the area is secure from the general public. Distribution panels shall be labeled "DP-1, 2, 3," etc. The following table shall be used in sizing distribution panels for future space allocation.

| Distribution Panel Sizing | | |
|---|---|---|
| Maximum Active Poles | Minimum Spare Poles | Total Poles |
| 12 | 6 | 18 |
| 24 | 6 | 30 |
| 36 | 6 | 42 |
| 42 | 24 | 66 |
| 66 | As required | 66+ required spaces |

Laboratories, toilet rooms, or other rooms requiring floor drains or plumbing in the floor shall not be located directly above electrical rooms or closets.

Branch circuits shall not be served from panelboards located in an adjacent building, area, wing, or a different floor, except for buildings with interstitial utility distribution where branch circuit panels are located on the interstitial floors. Exceptions for circuits with panelboards

on a different floor are lighting and power within vertical stairways, elevator shafts, roofs, and telecommunication areas with dedicated panelboards.

Panelboards shall have a 100% neutral bus and a ground bus. Panels serving high harmonic load content (more than 50% nonlinear load) shall have a 200% neutral bus. All panelboard breaker busing (extension fingers), including spaces, shall be rated for 100 A minimum for panelboard rated 400 A and higher, and a minimum 60 A for panelboards rated 250A or less. All panel boards shall be provided with copper bussing.

Branch circuit panelboards with ampacities greater than 100 A shall have 42 poles. Branch circuit panelboards shall be three-phase, four-wire.

Single panelboards 400 A and above shall be provided with a full height piano hinged trim. All dual-section panelboards shall have a full piano hinge for each section. The trim shall hinge open with the removal of a few screws. The panel door giving access to the circuit breakers only shall have a flush tumbler lock. All panelboard doors within a building shall be keyed alike. New panelboards installed within an existing building shall be keyed to match the existing panelboards.

## K. Voltage:

The secondary service voltage selection shall be based on load. The preferred voltage is 480/277 V. Typically a building load of 750 kVa or less could operate on 208/120 V unless there are compelling reasons to use 480/277 V. An economic analysis shall be performed to determine the best choice of voltage rating where the decision is unclear.

The standard voltages for service, electric heat, and motors are delineated in the tables below:

| Standard Voltages | | | |
|---|---|---|---|
| Voltage | Phase | Wire | Description |
| 13.8kV | 3 | 3 | Primary voltage |
| 4160/2400 V | 3 | 4 | Large motor voltage, power plant only |
| 480/277V | 3 | 4 | Preferred secondary voltage |
| 208/120V | 3 | 4 | Optional secondary service voltage and receptacle utilization voltage |

- Lighting-fluorescent or HID-277V (120V, if building service is 120/208 V).

- Incandescent lamps (shall be used only if required in Program of Requirements (POR) 120 V).
- Heating (electrical heating in any space greater than 3kW only if a request for variance is submitted and approved).

| Electric Heat Voltage and Phase | |
|---|---|
| Size | Voltage and Phase |
| Above 3 kW | 208 V or 480 V, 3-phase |
| Between 3 and 1.5 kW | 208 V or 480 V, 1-phase |
| Less than 1.5 kW | 120 V, 1-phase |

- Motors shall be rated 115/120 V for 120 V systems, 200/208 V for 208 V systems, and 460/480 V for 480 V systems. Motors furnished at single phase as integral parts of variable air volume terminal units are acceptable for all horsepower (hp) ratings.

| Motor Voltage and Phase | | |
|---|---|---|
| Size | Phase | Voltage |
| 0.56 kW (3/4 hp) and above | 3-phase | 208 V or 480 V |
| 0.37 kW (1/2 hp) | 1- or 3-phase | 208 V or 480 V |
| 0.25 kW (1/3 hp) and below | 1-phase | 120 V |

## L. Motor Control:

Thermal manual motor starters shall be of the non-automatic resetting type and shall be lockable in the off position. Single phase fractional horsepower, 0.37 KW (1/2 hp) and below, motor disconnects shall have overload elements sized per full load current of motor being protected. Disconnecting means for both line and control circuits shall be provided. Three phase motor starters shall be sized by the NEMA rating. Motors 37.3 kW (50 hp) and larger shall have reduced voltage starters including the Variable Frequency Drives (VFD) bypass circuit. VFD when provided shall adhere to the requirements listed under HVAC Section 6-2-00-H.2 “Variable Frequency Speed Drives”.

Motor starters shall be a combination type with a fused disconnect or a motor circuit protector. Three phase motor starters shall have integral single phase protection against loss of any phase voltage. Solid state overload relays provide this function inherently. Pilot devices to be included in three phase motor starters are:

- Red LED running pilot light.
- Green LED power available pilot light.
- Hand-off-automatic (HOA) switch.
- Control power transformer (CPT) with two primary and one secondary fuse, with secondary voltage of 120 V.
- Two normally open (NO) and two normally closed (NC) auxiliary contacts with provision for four additional auxiliary contacts.
- Mechanical override to open the starter enclosure while energized.

Motor Control Centers (MCCs) shall be provided where four or more motors are located in an area. MCCs shall have copper bus and plug-in starters, with no hard wiring directly to the starter. All control wiring (in or out) shall be extended to terminal strips in a central location in the MCC in accordance with NEMA Standard ICS 2-322, Type C wiring. Motor starters shall conform to IEC 947-4-1 Type 2 component protection in the event of a short circuit. VFDs shall not be installed in MCCs.

Ladder diagrams and sequences of operations shall be provided for all control functions. This applies to HVAC, automatic temperature controls (pneumatic or electric), plumbing, fire protection, security, programmable lighting control, etc.

Motor starter enclosures shall be NEMA Type 1 indoor, NEMA Type 4 outdoors, and NEMA 4/4X in pressurized water use or corrosive environments. High efficiency motors shall have the overcurrent protection sized per manufacturer's recommendations. Power factor correction capacitors shall be applied to motors 7.5 kW (10 hp) and larger. The capacitors shall be wired directly to the motor terminals.

# 10-3-10 Design Guidance

## A. Load Calculations:

Preliminary load calculations shall use the information in the table below, early in the design. Actual design demand load shall be used in the later part of the design. The following load figures in VA/m$^2$, gross area, shall be used in calculating the overall building load. These figures are to be used only for the electrical equipment sizing, not for mechanical equipment sizing.

| Normal Power Load Calculations | | | |
|---|---|---|---|
| Area | Laboratory | Animal | Other |
| Load | VA/m$^2$ (VA/sq. ft.) | VA/m$^2$ (VA/sq. ft.) | VA/m$^2$ (VA/sq. ft.) |
| Lighting | 27 - 38 (2.5 – 3.5) | 27 - 38 (2.5 – 3.5) | 27 - 32 (2.5 – 3.5) |
| Receptacles | 48 – 215 (4.5 – 20) | 22-43 (2 - 4) | 32 (3) |
| HVAC | 97-108 (9 – 10) | 97-108 (9 – 10) | 22-43 (2 - 4) |
| Laboratory Equipment | 43-86 (4 – 8) | 43-86(4 – 8) | |
| Elevators | 11-16 (1 – 1.5) | 11-16 (1 – 1.5) | 5-11 (0.5 – 1) |
| Miscellaneous | 11-22 (1 – 2) | 11-22 (1 – 2) | 11 (1) |
| Total range | 237-485 (22 – 45) | 211-313 (20 – 29) | 97-129 (9 – 12) |

## B. Transformer Location:

The optimal location for transformers is indoors in a transformer vault, located separately from the service entrance switchgear room, and not in the same room as the emergency power distribution gear. The secondary service bussing shall be kept as short as possible and electrically the same length. An alternate location is outdoors in a pad mounted configuration.

## C. Transformer Removal Route:

The size of transformers and the requirements for power reliability at the NIH require that an exit route is specified for these large, heavy items of electrical equipment. The A/E design shall provide for a permanent exit route to remove these large items and bring in new units. See Structural Chapter 5 Section 5-1-00-C “Equipment Pathway.” The A/E shall specify the use of painted stripes and warning signs on the floor and walls along the exit (re-

moval) route. The faulty unit shall be capable of being removed while the other transformer(s) remain in place and in operation.

### D. Load Segregation:

Wherever possible loads shall be segregated into like groups based on function (i.e. laboratory, office, animal research facility, etc.) or type of load (i.e. computers, motors, lighting, receptacles, etc).

### E. Reliability:

The A/E shall evaluate the degree of reliability required. Design issues such as separately routed primary feeders, two versus multiple network transformers, transformer placement, and switchgear location influence the reliability issue. Refer to Section 10-5 Emergency Power for requirements/guidance on emergency power. The value of the work being performed in a building and the impact on research due to an outage shall be considered.

## 10-3-30 Design Document Requirements

### A. Tools and testing equipment:

Project specifications shall require that specialized tools necessary for installation, maintenance, calibration, or testing of electrical equipment are supplied with the associated equipment and turned over to the government at the end of the construction project. Examples of specialized tools include a special screwdriver for vandal-proof lighting fixtures or the very complex test and calibration equipment needed to maintain solid-state circuit breakers. Non-compliance shall be cause for non-acceptance of the equipment.

### B. Testing:

Acceptance testing of primary cable, primary switches on network transformers, network protectors, secondary switchgear, Power Circuit Breakers, MCCs and grounding system shall be performed in accordance with NETA specifications. The minimum tests required for the given equipment are shown in the following table.

| Tests Required for Electrical Equipment | |
|---|---|
| Equipment | Test |
| 15 kV Cable | Insulation resistance |
| 15 kV Oil switch | Visual; Contact resistance; Insulating liquid |
| Network transformer | Visual; AC high-potential test on primary windings & switch; Insulation resistance (2500 V megger) on primary |

| Tests Required for Electrical Equipment | |
|---|---|
| Equipment | Test |
| | and secondary windings; Turns ratio on all tap positions; Insulating liquid Envirotemp FR3 oxygen percentage; FR3 (six individual tests) including dielectric breakdown voltage; FR3 dissolved gas analysis |
| Network protector | Visual and mechanical; Insulation resistance Current transformer ratio; Contact resistance Minimum pickup voltage |
| Secondary switchgear | Visual and mechanical; Insulation resistance High potential; Instrument transformers |
| Power circuit breaker | Visual and mechanical; Insulation resistance Pickup and time delay values; Operation |
| MCCs | Visual and mechanical; Insulation resistance Overload; Bus and starters |
| Grounding electrode | Fall of potential |
| Ground fault | Visual and mechanical; Neutral to ground resistance; Pickup and time delay |

# Section 10-4: SCADA System



## 10-4-00 Design Requirements

This section describes the level of support an NIH Project/Program must provide to successfully interconnect and support remote monitoring and control of low and medium voltage electrical switchgear, transformers, and associated equipment by the NIH Campus SCADA System.

The intent of this section is to ensure that each new or renovated building or equipment location is designed and constructed to properly interconnect and operate with the campus SCADA system. This section is not intended to require an independent SCADA system in any building or equipment location on the NIH campus unless otherwise requested and justified by the sponsoring project/program. The existence of a local SCADA system in any building or equipment location on the NIH campus does not relieve the project/program of meeting the requirements to interface with the NIH SCADA system.

### A. General Requirements:

The following indicates the minimum requirements for all buildings on the NIH campus:

- The NIH campus SCADA system is designed to monitor and control devices installed in substations, switching stations and load centers (buildings) throughout the NIH campus. Substations and switching substations shall be designed and built to integrate with the NIH campus SCADA system and shall support remote monitoring of all designated equipment and the remote control of circuit breakers through the SCADA system. Designer should take into consideration, a load add/shed scheme with programmable prioritization.
- Building electrical distribution systems (load centers (buildings)) shall be designed to integrate with the NIH campus SCADA system and shall support remote monitoring of all designated equipment and shall support remote control of main and bus tie circuit breakers, network protectors, and ATSs.

- Neither the campus SCADA system nor local control and protection shall interfere with the operation of the other. All communications and control interfaces shall be wired to ensure that trouble shooting or temporary disconnection shall not require any building outage or loss of service as applicable. The SCADA Substation Automation Platforms (SAP) shall require single or multimode fiber optic connectivity from the SAP in the substation, switching station or load center to a designated location where it shall connect into the NIH facNET LAN.
- All substations, switching stations and load center (building) projects shall be responsible for providing the material and labor needed to interface the new or renovated substation, switching station or load center with the NIH SCADA master station. At a minimum, the project shall cause the following equipment to be provided.

## B. Specific Requirements:

### B.1 Substation Automation Platform:

The following requirements are for all SAPs and shall be specified in the contract documents:

- Each substation, switching station and load center shall be equipped with a SAP of the appropriate type and size to communicate with the NIH SCADA master station. The SAP is a highly customized device designed for installation inside substations, switching station and load centers (buildings) throughout the NIH campus. The SAP performs a number of critical functions including: communication with the NIH SCADA master station; repository for the local SCADA database; protocol conversion (between the master station SCADA and numerous field devices); and communication with the IEDs installed within the substations and load centers (buildings).
- SAPs that are installed in substations are designed to operate on 125V DC and do not require additional power. SAPs designed for installation in switching stations and load centers (buildings) require the installation of an uninterruptible power supply (UPS). The contractor shall provide an UPS system as part of the SAP package so that it can be installed, wired and tested prior to shipment.
- To assure security for the NIH SCADA system, each SAP shall communicate with the NIH SCADA master station over a virtual private network (VPN). A specialized VPN network supports NIH SCADA system communications and can accommodate substantial growth. As part of procuring an SAP, the SCADA vendor shall furnish, install, setup, and demonstrate successful VPN communications between the new SAP and the NIH SCADA master station.
- Each SAP is designed to interface and communicate with local IEDs (meters, Programmable Logic Controllers (PLCs), controllers, etc.,) using any number of standard and

proprietary communication protocols. Physical communications shall take place over RS-232D, RS422, or RS-485 communications links installed by the contractor and approved by the SAP manufacturer.

- The contractor shall identify the manufacturer, make, model, quantity, and communication protocol used for each IED to be monitored by this SAP. Additional information, such as register number, point name, scaling, etc., may also be required to successfully interface with IEDs; this information shall be available to the SAP manufacturer as soon as possible so that the SAP can be properly configured prior to delivery to the NIH campus.
- Adequate wall space shall be identified and reserved within the substation, switching station or load center to mount the SAP. Substation and switching station SAPs typically occupy 1,015 mm (40 in.) wide x 915 mm (36 in.) deep x 2,440 mm (8 ft.) high . Load center SAPs are wall-mounted NEMA cabinets, typically occupying 1,015 mm (40 in.) wide x 915 mm (36 in.) deep x 1,015 mm (40 in.) high.
- A dedicated 120 V AC 20A duplex receptacle shall be installed directly adjacent to the location where the SAP shall be mounted. The circuit shall be supplied from a single 20 amp circuit breaker that does not feed any other loads. The SAP is custom designed and shall be compatible with existing NIH campus components and systems.

## B.2 Intelligent Electronic Devices (IEDs):

Each substation “main” supply feeder and outgoing feeder breakers shall have a metering device installed to measure and report energy utilization, operational data locally, and, upon request, to the local SAP device.

A system that is compatible with the current NIH campus monitoring system shall be provided. The contract documents shall include the following specifications:

- For substation “main” supply feeders or transformer secondary feeders, provide a circuit monitor compatible with the existing NIH campus components with the panel meter and bezel mounting.
- For substation, switching station and load center loads provide a circuit monitor compatible with the existing NIH campus components with the panel meter and bezel mounting.
- A voltage disconnect and current shorting test switch. The test switch shall be compatible with the existing NIH campus components and wired in series with each circuit monitor being installed to allow the servicing of circuit monitors without the need to de-energize the associated circuit. See Exhibits X10-4-A and X10-4-B for an example of this type of installation.

## B.3 Status Programmable Logic Controller (PLC):

The contract documents shall require the contractor to provide and place in service PLCs to monitor the status of power circuit breakers, network protectors, and various alarms throughout the substation, switching station or load center. Additional PLCs shall be provided as required, to properly provide status of all monitored devices. The PLCs shall be located inside a local switchgear cabinet (if space is available). Otherwise, a separate NEMA cabinet shall be provided to house the PLC(s).

PLCs shall be compatible with the existing NIH campus components with the following configuration:

- PLC 24v DC, 16 or 32 inputs, 170 ADI 340 00.
- I/O base, 170 XTS 004 01.
- Modbus RTU (RS232/485) TOD clock, battery backup, 172 JNN 210 32.
- 24v DC power supply (one required for up to five PLCs), 170 CPS 111 000.
- Provide conduit, conduit hangers, conduit couplers, four-conductor 22 AWG stranded wire between the RS-232 port of the PLC and the location of the SAP device within the substation, switching station or load center. An additional 3,660mm (12 ft.) of wire shall be left at the SAP end to allow for routing the wire to its final connected position.
- Provide conduit, conduit hangers, conduit couplings, two-conductor, 22 AWG stranded wire between the PLC input terminals and each monitored circuit breaker cubicle, network protector enclosure, and transformer alarm cabinet. Terminate status wires per project requirements.

## B.4 Circuit Breaker Status:

Each substation “main” supply breaker, transformer secondary breaker, bus tie breaker, and feeder breaker shall have its status monitored by the NIH SCADA system. A spare breaker status contact in each breaker to be monitored (“Type A” closed when the breaker is energized) shall be connected to the status and common lead from the status PLC. Each PLC status point shall be clearly labeled and identified as to the device whose status it represents. This information shall be left in the substation, switching station or load center to aid in maintaining the equipment. Breaker status shall represent the state of a single device, not multiple devices.

## B.5 Network Transformer Protector Status:

Each load center transformer network protector shall have the status of the network protector mechanism monitored by the NIH SCADA system. A spare network protector status contact shall be identified and/or installed in each network protector to be monitored (“Type A” closed when the protector is closed) and the status and common lead connected from the

status PLC. Each PLC status point shall be clearly labeled and identified as to the device whose status it represents. This information shall be left in the substation, switching station or load center to aid in maintaining the equipment. Network protector status shall represent the state of a single device, not multiple devices.

## B.6 Transformer Alarms:

Each substation, switching station and load center where transformers are installed shall have the transformer alarms wired from the transformer alarm cabinet to a point on the status PLC. The following transformer alarms shall be paralleled inside the transformer alarm cabinet resulting in two alarms per transformer:

- Transformer liquid level or transformer tank pressure (low or high) or transformer temperature.
- Transformer sudden pressure.

The alarm contact assignments of the transformer manufacturer shall be identified and the PLC status wires connected to contacts that are open when the transformer alarm condition is NOT present. Each PLC status point shall be clearly labeled and identified as to the device whose status it represents. This information shall be left in the substation, switching station or load center to aid in maintaining the equipment. Each individual transformer's alarms shall represent the state of a single device, not multiple devices.

## B.7 Breaker Control Panel (Required for Remote Breaker Control):

Substations, switching stations` and load centers (buildings) equipped for remote SCADA control shall have a breaker control panel (BCP) installed to provide field maintenance and operating personnel with a high degree of personal safety when operating moderate and high-voltage switching equipment. The BCP shall be installed in an area of the substation or load center that does not require operating personnel to stand directly in front of circuit breakers when opening or closing them.

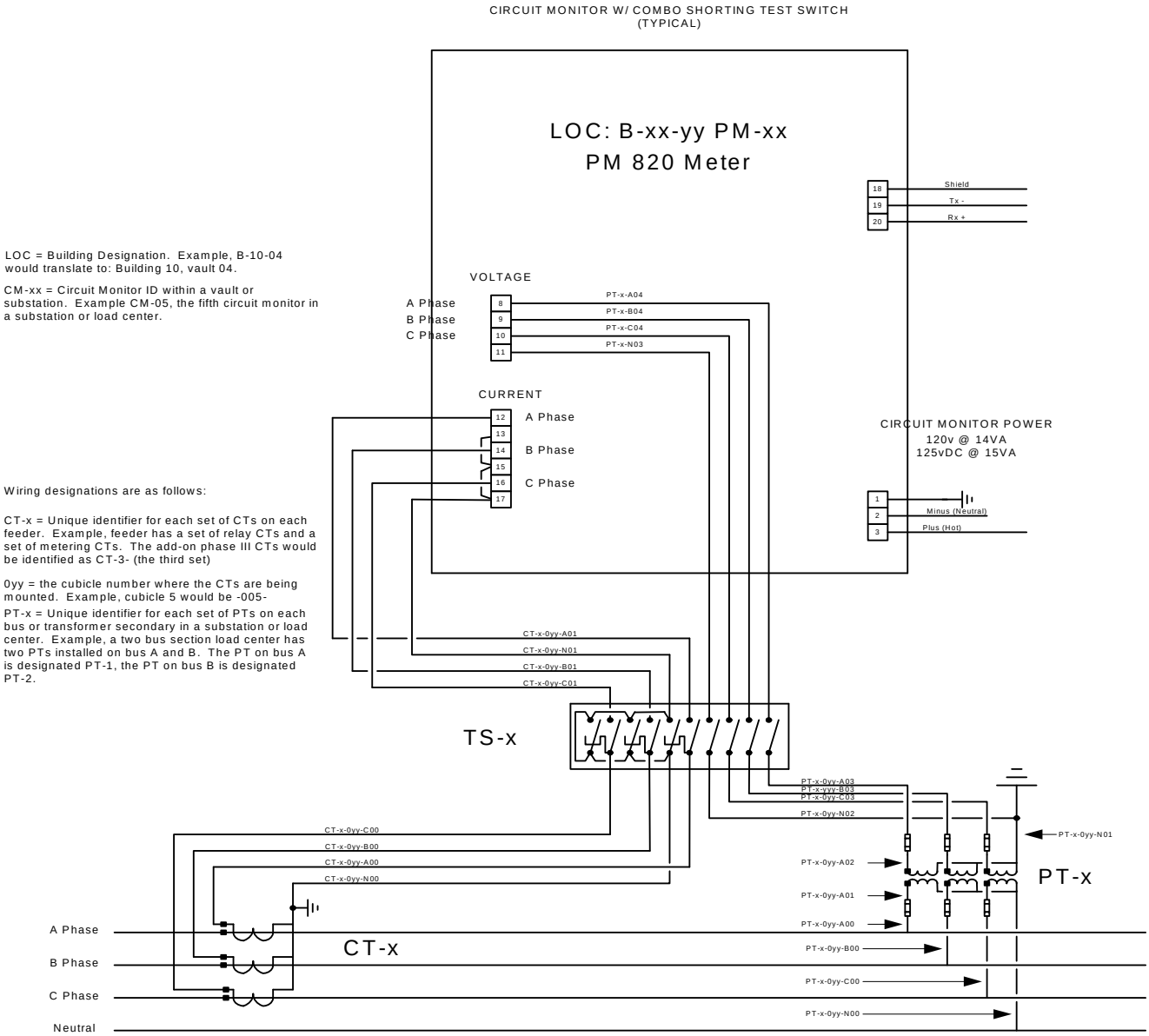
Each BCP shall consist of a NEMA cabinet of sufficient size to accommodate the required number of breaker control switches, open/close breaker status lights, and a local/supervisor switch that allows operating personnel to remove remote control when doing maintenance. See Exhibit X10.4-C Figure 2-1 for an example of a BCP.

## 10-4-20 Design Information

### A. Project/Program Responsibilities:

Due to high ground currents that can be present under certain electrical faults, no copper network wiring (CAT-5 or CAT-6) shall enter the substation or load center. Project specifications shall include the following contractor procedures for the SAP:

- Arrange for the SAP manufacturer to commission and startup the SAP.
- Provide and startup all required IEDs. Verify that the SAP and associated IEDs are functioning properly.
- Provide all test switches.
- Provide and startup all status PLCs.
- Provide one copy of “As Built” switchgear and equipment drawings to the NIH Utilities Branch to aid in future maintenance of equipment.




LOC = Building Designation. Example, B-10-04 would translate to: Building 10, vault 04.

CM-xx = Circuit Monitor ID within a vault or substation. Example CM-05, the fifth circuit monitor in a substation or load center.

Wiring designations are as follows:

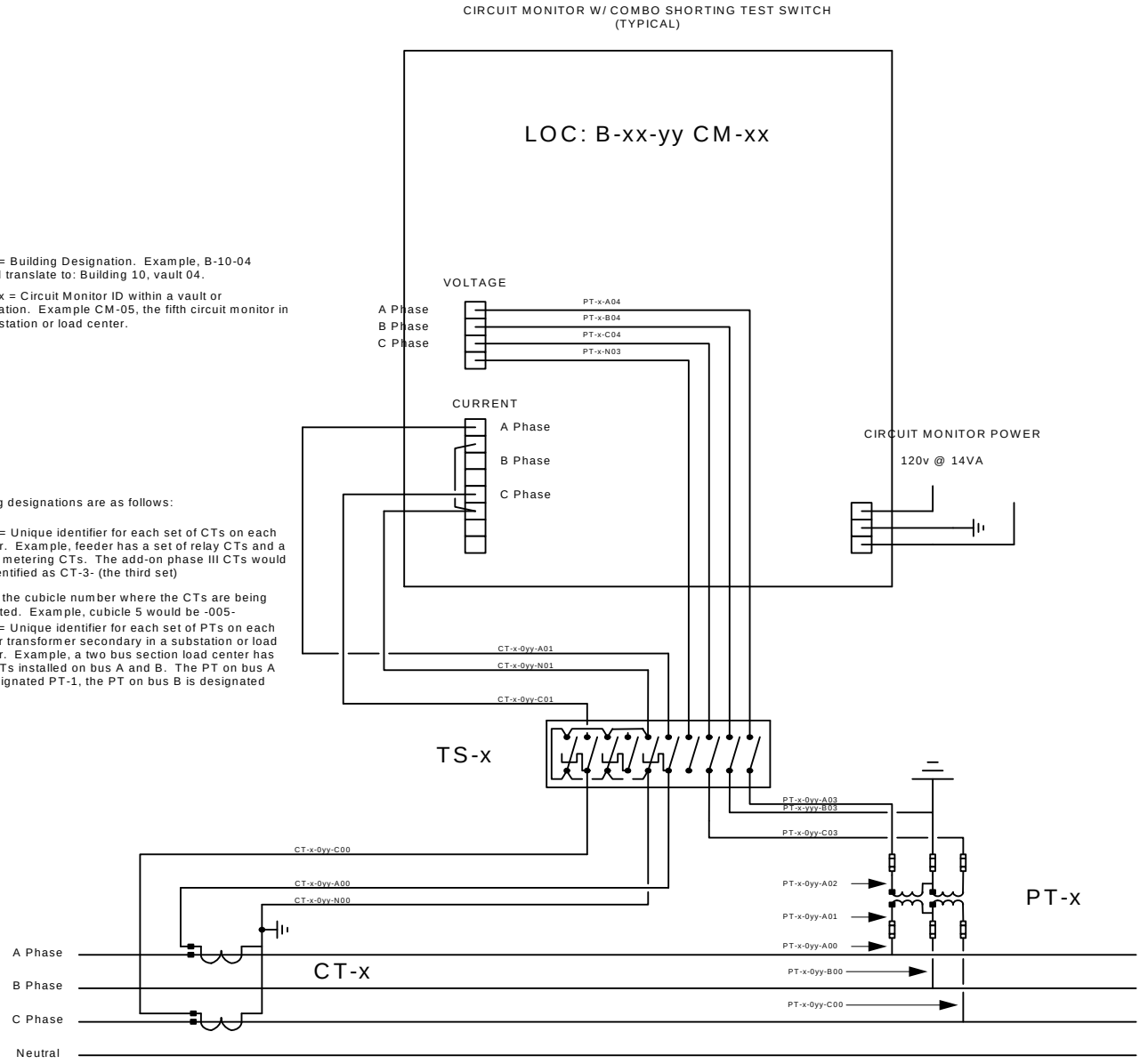
CT-x = Unique identifier for each set of CTs on each feeder. Example, feeder has a set of relay CTs and a set of metering CTs. The add-on phase III CTs would be identified as CT-3- (the third set)

0yy = the cubicle number where the CTs are being mounted. Example, cubicle 5 would be -005-

PT-x = Unique identifier for each set of PTs on each bus or transformer secondary in a substation or load center. Example, a two bus section load center has two PTs installed on bus A and B. The PT on bus A is designated PT-1, the PT on bus B is designated PT-2.

3-Phase, Four Wire Connected CTs and PTs. (Type 40)

FIGURE 1-1




Delta/Delta connected CTs and PTs.

FIGURE 1-2

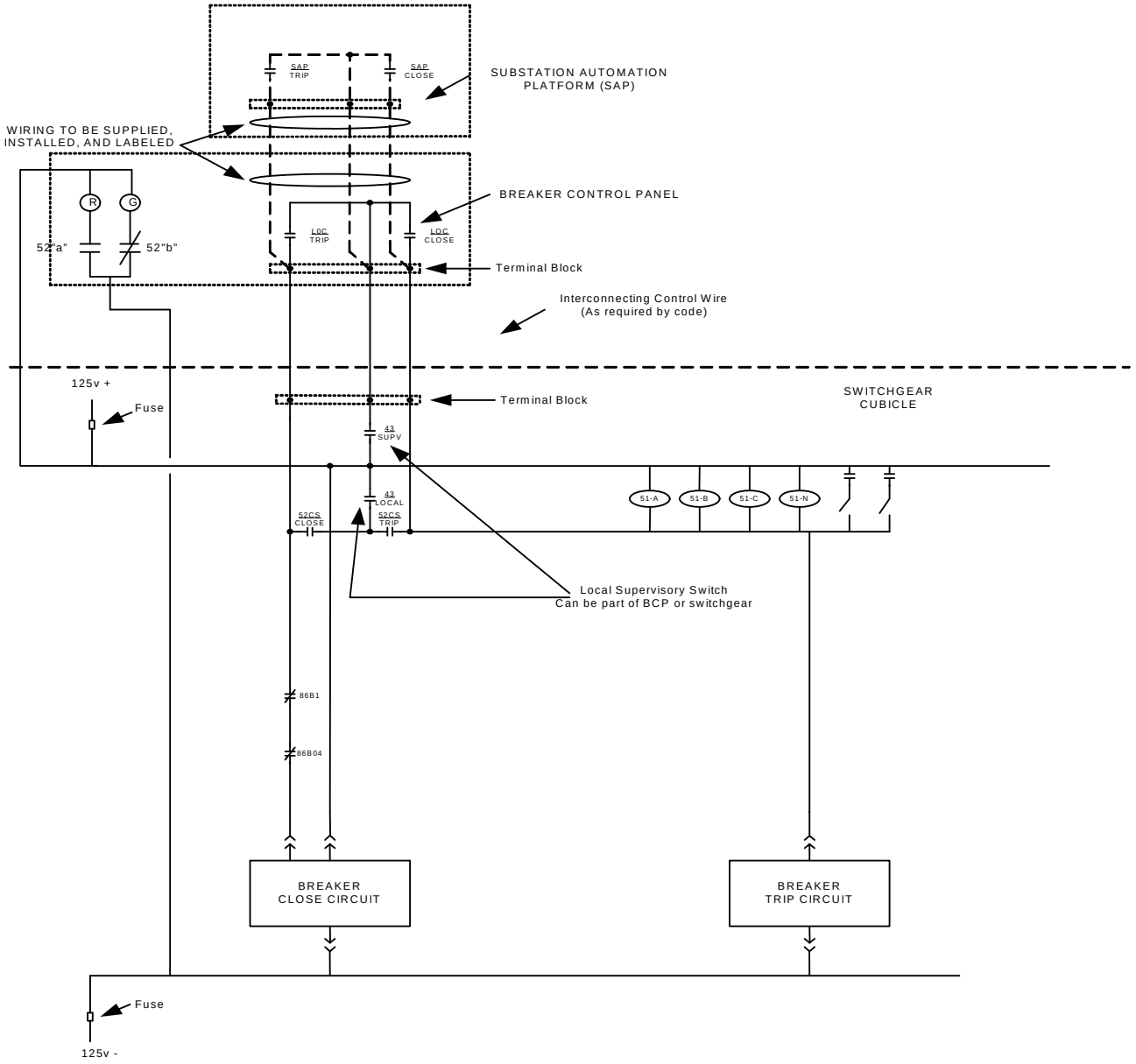

SAP TRIP
SAP CLOSE
SUBSTATION AUTOMATION PLATFORM (SAP)
WIRING TO BE SUPPLIED, INSTALLED, AND LABELED
BREAKER CONTROL PANEL
R
G
52"a"
52"b"
LOC TRIP
LOC CLOSE
Terminal Block
Interconnecting Control Wire (As required by code)
125v +
Fuse
Terminal Block
SWITCHGEAR CUBICLE
43 SUPV
43 LOCAL
52CS CLOSE
52CS TRIP
51-A
51-B
51-C
51-N
Local Supervisory Switch
Can be part of BCP or switchgear
86B1
86B04
BREAKER CLOSE CIRCUIT
BREAKER TRIP CIRCUIT
Fuse
125v -

FIGURE 2-1

# Section 10-5: Emergency Power



## 10-5-00 Design Requirements

Life safety loads shall be wired separately from normal powered, legally required and optional standby loads. The following indicated devices shall be connected to the life safety emergency power system:

- Emergency egress lighting.
- Egress signage.
- Communications systems (including PA systems).
- Fire alarm systems.
- Self-contained, battery-powered lighting at generator set location
- Medical gas alarm systems
- Fire suppression systems (fire pumps, compressors, valves, etc).
- Security, intrusion detection and access control systems.
- Building Automation Systems including control air compressor (Buildings with smoke evacuation or animal facilities).
- Automatic doors used for egress.
- Elevator cab lighting, control, communication and signal systems
- Generator day tank pump

The following systems shall be considered legally required standby loads and shall be connected to the emergency power system:

- Fire department receptacles.
- Pumps, components and all devices associated with fuel stored in large storage tanks serving the emergency generator.
- Sewage ejector systems.
- Sump pumps.
- Sump dewatering pumps.
- Lighting provided at the generator.
- Critical supply and exhaust fans.
- Operating rooms.

- One elevator per bank of elevators. All elevators shall be on emergency power with only one elevator per each bank of elevators to run at a given time. The lock-out of the elevators shall be provided by the elevator controller.
- Building Automation Systems including control air compressor
- Air handling system serving the elevator machine room when elevators are on emergency power.
- Air handling systems associated with active smoke purge/evacuation systems.
- Medical Gas systems.
- Fume hood exhaust fans.

The following systems shall be considered optional stand-by loads and shall be connected to the emergency power system:

- UPS systems.
- Automatic temperature control system components.
- Auxiliary mechanical equipment that supports heating and cooling systems.
- One light fixture per module per laboratory minimum.
- Biosafety cabinets, incubators, biobubbles, containment devices, etc.
- Supply and exhaust fans for animal areas.
- Laboratory equipment alarm monitoring system.
- High-value specimen refrigerators, freezers, cold rooms, warm rooms, etc.
- Closed circuit television cameras and associated equipment.
- Lighting control systems.
- Select lighting in electrical distribution equipment and mechanical rooms.
- Lighting in animal facilities, if defined by program requirements.
- Computer room air handling units
- Air-conditioning units serving main telecommunication room.
- Water chillers, cooling towers, pumps and associated systems, which serve critical areas.
- Heating systems including: boilers, heating water pumps and associated fuel oil system.
- Steam condensate pumps.
- Domestic water pumps
- Hands free toilet flushers and lavatory faucets.
- Electrical heat tracing for hydronic piping
- Critical scientific equipment identified by program requirements.

## A. Generator:

Generator installation and start up procedures shall follow NFPA 110. All generators and fuel supply shall be located in a secure area. All generators, transfer equipment, paralleling equipment, and emergency switchgear shall be installed above grade.

Generators shall be:

- Located where easily accessible for service and future replacement.
- Installed with provisions to avoid structure-borne vibration.
- Located away from high ambient temperatures.
- Protected from the weather and from vandalism.
- Located close to the main power consuming equipment.
- Provided with at least 1.2 m (4 ft.) of clearance around the generator set. There shall be access for replacing the generator without moving the generator set or accessories, such as a day tank.
- Located where engine, fan, and exhaust noise levels shall be acceptable.

The optimal generator location is outdoors in a sound-attenuated enclosure with adequate working space around the generator. The sound-attenuated enclosure shall provide 70 to 79 dB maximum noise level 6 m (20 ft.) from the enclosure at rated output, regardless of generator size. Power and monitoring wiring shall be provided for the remote tank level gauge. Self-contained, battery powered lighting shall be provided on both sides of the generator(s) connected to emergency power.

The generator exhaust silencer, or muffler, shall be rated for minimum residential use or quieter to achieve the required sound rating. Generator exhaust discharge location shall be determined by a wind wave analysis. The location and direction of the engine exhaust shall not adversely affect air intake for the building or adjacent buildings. The exhaust shall be directed up to maximize sound attenuation. A hinged rain cap shall be provided on vertical discharge exhaust pipes.

If site constraints are such that the generator shall be located indoors, the following design requirements apply:

- Sound attenuated room shall be provided to suit the generator being installed and the surrounding occupancies.
- The design for the volume of air delivered to the interior space where a generator is located shall include the combustion air that exits the exhaust stack and the cooling air that flows through the radiator (air that flows through the engine radiator is heated, and this expanded air, if used for combustion, reduces engine efficiency).

- The cost of conditioning the air used for the needs of a generator shall dictate that outside air be used wherever possible. This requirement has no impact on combustion air, but cooling with outside air shall require that the coolant in the generator contain a chemical antifreeze ingredient.
- The outside air intake for combustion air shall be coordinated so that there is little chance that building exhausts (which may contain smoke during in a fire) shall be drawn in for combustion air.
- The ventilation air intake shall be coordinated so that it does not draw in engine exhaust.
- The design shall take into account the additional cooling air if load bank is unit mounted.
- Air intake louvers shall require fast opening before pressurization of the intake plenum to avoid damage to louvers.

Where the engine exhaust from the indoor generator exits the building through a wall or penetrates interior floor slabs or the roof, an insulating thimble shall be used to protect adjacent materials from the excessive heat that would be created by full load operation. The design that places a generator within a new building shall also provide a suitable exit route for removal of this equipment if replacement is necessary in the future. This route shall be clearly delineated on the drawings and in the field by painted lines on the floor, walls, and so on.

The air for either cooling or combustion purposes shall be primary filtered as it enters the building from outside. The engine filter shall be considered a second and final filter for indoor units.

All generators 1,500 kW and above shall have permanently installed fully rated load banks. For generator less than 1,500 kW, a connection point for load testing with a portable load bank shall be provided. This connection point is also suitable for use of a portable generator if interlocking means are provided to prevent concurrent operation of normal and emergency power. All necessary wiring for load bank testing with proper external building terminal connections shall be provided. A shunt trip circuit breaker shall be provided for connection to the load bank. The load dump control circuit in the load bank shall be wired to the transfer switch(es). If the building calls for emergency power while the generator is being exercised by the load bank, the load bank circuit breaker shall immediately open, dropping the load bank from the generator bus. The quantity of lugs based on parallel #500 MCM cables shall be provided for connection to a portable load bank. An accessible driven ground rod tied to the electrical grounding system shall be provided at the portable load bank connection location.

An onsite minimum fuel storage capacity of 24 hours run time at 100% generator nameplate load shall be provided. For locations other than Bethesda campus minimum fuel storage

capacity of 48 hours run time at 100% generator nameplate load is recommended. Fuel-tank leak detection shall be provided.

The fuel supply line from the storage tank to the day tank shall have a hand-operated pump of the crank type, as well as an electric pump in non-gravity locations. The overflow line from the engine shall be returned to the storage tank, not the day tank. In gravity situations where the main fuel tank is higher than the generator, a "reverse day tank" (return storage tank) shall pump excess fuel back to the main tank. Fuel lines shall not be routed on the surface of the floor or anywhere subject to wear or physical damage.

Provide Building Automation System (BAS) monitoring of main storage and generator day tank high level and critical high level alarms as well as fuel tank rupture alarm.

The generator day tank pump and battery charger shall be connected to emergency power. The jacket water heaters shall be connected to normal power. Where an oil circulation pump is provided to circulate oil through the engine top end, it shall be connected to normal power. Isolation valves shall be provided to allow for jacket water heater replacement.

## A.1 Automatic Transfer Switches (ATSs):

All life safety and legally required systems shall utilize ATSs. Other loads on generator systems may utilize transfer schemes. In either scenario, "break before make" switches shall be utilized to prevent the overlap of normal and emergency power.

Where two or more ATSs are installed, an emergency diesel distribution panel (EDDP) shall provide for future addition of ATSs with minimal interruption to the diesel power system. The EDDP and all other emergency gear up to the load side of the ATS shall be located separately from the normal power switchgear room.

The number of switched poles (three or four) in a transfer switch shall match the existing number of switched poles where replacement or upgrade is occurring. The lifting of the generator neutral to ground bond shall comply with NEC requirements for three-pole, solid neutral transfer switches. New construction and complete renovation projects shall utilize four-pole switches on three-phase, four-wire systems. The generator neutral shall be grounded when using four-pole switches in accordance with NEC requirements.

ATSs shall have override switches to cause them to transfer to the other source only if it is a "good source," defined as one with line voltage ±10% available and frequency of 60 Hz ± 0.5%. ATSs shall allow for a safe transfer of power source via an external manual operator (EMO) to mechanically operate the ATS under load. Pushbuttons shall not be used as

EMOs. The EMO shall transfer the switch to any position regardless of the condition of the source. ATSs without center off-time delay shall have an in-phase band monitor. ATSs shall have center off-time delay when serving motors. ATSs shall be located indoors. If a waiver is granted for an outdoor location, the ATS shall have door-in-door NEMA Type 4X construction with strip heaters inside the enclosure. The strip heaters shall be connected to emergency power. The transfer switch shall be UL listed in accordance with UL 1008.

The ATS shall be provided with a microprocessor-controlled, complete metering package supplied on the load side of the device. These digital meters shall monitor the load whether the source is normal or diesel power. At a minimum, metering shall consist of a voltmeter that measures all three phases simultaneously, ammeter, frequency meter, kW meter, and power factor (PF) meter plus analog bar graph for easy reading of voltage and current.

The operating mechanism of the transfer switch shall be electrically operated and mechanically held. ATSs shall not be manufactured utilizing two circuit breakers with the trip handles physically connected. ATSs shall be provided with rack-out mechanisms for removal while load is still connected.

Bypass type transfer switches shall be used. With a bypass switch, the transfer switch can be taken out of service with only a momentary outage to the load. The size of a transfer switch increases with the addition of the bypass function. The bypass switch shall be capable of manual operation to either source under load, regardless of the condition of the source or transfer switch position. The manual operator shall be readily and permanently accessible without opening the enclosure door.

## A.2 Bypass Breaker:

A bypass circuit breaker may be provided so that in an extended power outage the surplus generating capacity of the onsite generators can be shunted to non-emergency loads. Where a bypass breaker has been provided for this purpose, the bypass breaker shall be key interlocked to prevent any possibility of normal power being connected in parallel with the local generator when normal power is restored.

## B. Generator Receptacles:

The use of an onsite diesel generator is a requirement for most research activities. Where an onsite diesel generator is deemed necessary, generator receptacles for connection of a small NIH-owned portable generator may also be required. These determinations shall be made on project-by-project basis. Generator receptacles shall be provided on all installations where a generator is not required or provided. Currently, the largest sized NIH portable generator is 1540kW.

Generator receptacles shall be located 1 m (3 ft.) above finished grade at or near an accessible roadway, parking lot, or loading dock. A receptacle bank shall include the following devices, compatible with the existing NIH campus components and systems:

- 200 A, 480/277 V, four-pole, five-wire junction box, angle adapter, and pin and sleeve receptacle, with either integral or separate series rated over current protective device where receptacles are parallel. The quantity of parallel 200 A receptacles shall match the generator output.
- One 15 A, 125 V, two-pole, three-wire NEMA Type 5-15R with a flip-lid cover for 120 V AC load bank control or battery charger.
- One 15 A, 125 V, two-pole, two-wire-locking NEMA Type L1-15R with a flip-lid cover for remote start circuit.
- One 20 A, 250 V, two-pole, three-wire-grounding NEMA Type 6-20R with a flip-lid cover for 208 V AC heater circuit.

The last three receptacles listed above shall be installed in a NIH approved box, directly adjacent to the boxes containing the receptacles, and the wiring may be combined with the larger power conductors.

Receptacles for portable generator crankcase heater and battery charger shall be connected to the emergency panel.

## 10-5-10 Design Guidance

The emergency power system shall be designed to meet applicable codes and standards. The values in the table below are for preliminary sizing only. Actual loads shall be incorporated during design.

| Emergency Power Load Calculations | | |
|---|---|---|
| Area | LABORATORY | ANIMAL |
| Load | W/m$^2$ (W/sq. ft.) | W/m$^2$ (W/sq. ft.) |
| Lighting | 1-5 (0.1 - 0.5) | 1-5(0.1 - 0.5) |
| Receptacles | 1-2 (0.1 – 0.2) | 1-2 (0.1 – 0.2) |
| HVAC | 1-32 (0.1 – 3.0) | 1-32 (0.1 – 3.0) |
| Laboratory Equipment | 16-43 (1.5 - 4.0) | 16-43 (1.5 - 4.0) |
| Elevators | 2 (0.2) | 2 (0.2) |
| Total range | 25-84 | 25-84 |

## 10-5-20 Design Information (Local Requirements)

### A. Fire Department Receptacles:

In compliance with Montgomery County Executive Order for Fire Department Mutual Aid, a single 20 A three-wire twist-lock receptacle (NEMA Type L5-20R) shall be installed on each level at least as high as the hose connection outlet to each standpipe. The receptacle shall be located in the corridor adjacent to the stairwell. Additionally, these receptacles are required at maximum 30 m (100 ft.) intervals in long corridors. Each outlet box shall be painted fire alarm red in color and be marked "ONLY FOR FIRE DEPARTMENT USE

A 20 A circuit per floor or a 30 A 120 V circuit for each standpipe riser to the above-listed stairwell twist-lock receptacles shall be provided. The receptacle shall be supplied from the emergency panel. The wiring method for exposed work shall be RGS conduit. Boxes shall be metal, weatherproof type, with gasketed flap-door covers and threaded hubs. The wiring method for concealed work shall be conduit with appropriate galvanized boxes having gasketed flap-door covers suitable for Fire Department use.

A duplex receptacle on the emergency system shall be placed in the corridor within 6 m (20 ft.) of each stairwell entrance. This receptacle is primarily for the use of the NIH Fire Department in emergency situations and shall be so marked with appropriate signage so that the receptacle shall not be blocked or hidden by equipment.

## 10-5-30 Design Document Requirements

### A. Testing:

Acceptance testing of generators and automatic transfer switches (ATSs) shall be performed in accordance with NETA specifications. The minimum tests required for the given equipment are shown in the table below.

| Tests Required for Electrical Equipment | |
|---|---|
| Equipment | Test |
| Generator | Visual and mechanical; Insulation resistance<br>Protective relay; Phase rotation |
| Automatic transfer switches | Visual and mechanical; Contact resistance; Insulation resistance; Relay settings;<br>Timer settings; Operation |

# Section 10-6: Power Quality



## 10-6-00 Design Requirements

### A. Grounding:

A solid grounding electrode system shall be provided to ground the service entrance equipment. Where a pad mounted transformer is utilized, a ground ring of #4/0 AWG bare copper conductors shall be provided around the transformer pad. Ground rods minimum 3 m (10 ft.) long, 19 mm (0.75 in) diameter copper-clad steel, shall be placed approximately 1 m (3 ft.) outside each corner of the pad. Two #4/0 AWG conductors shall be brought up into the transformer enclosure for equipment grounding. The transformer neutral shall be grounded only inside the service entrance (SE) equipment in the building. A #4/0 AWG ground conductor shall extend from the outdoor ground ring underground to the main electric room ground bus.

A similar ground ring of #4/0 AWG bare copper conductors shall be installed surrounding the main electrical room (or indoor transformer vault) with ground rods in each corner and maximum 6 m (20 ft.) on center around the perimeter of the room. Two #4/0 AWG ground conductors from the ground ring shall be connected to an accessible wall mounted ground bus at each end of the main electrical room ground bus.

Ground conductors leading to the ground ring shall be exothermically welded to the ground bus; all others shall be bolted. Grounding electrode conductors shall be labeled. Labeling shall utilize embossed brass metal tags with nylon tie wraps.

Ground conductors brought through the floor or walls shall be in PVC conduit sleeves. Ground conductors shall not be located in traffic areas or where subject to damage. However, where ground leads through the floor are subject to damage due to layout changes, the PVC sleeve shall be cut off flush with the floor. A steel “C” channel shall be placed face down over the penetration to form a protective bridge. The “C” channel shall be bolted to the floor with the ground wire exiting one end.

Provide ground test wells at accessible locations. For critical lab buildings, an active high impedance ground monitoring system shall be provided to continuously verify the integrity of the grounding system.

All feeders and branch circuits shall contain green, insulated equipment grounding conductors sized in accordance with the NEC.

Isolated ground receptacles may be required in laboratories and offices based on the program direction. Panelboards serving isolated ground receptacles shall have an isolated ground bus in addition to the equipment ground bus. The isolated ground bus shall not be bonded to the panelboard enclosure or equipment ground bus. The buses shall be clearly labeled. An isolated ground conductor shall be sized to match the phase conductors. The isolated ground conductor shall be connected to the panelboard's isolated ground bus and the separately derived power source's ground point.

All structural steel shall be grounded. All exposed metallic structures such as light poles, aerial structures, protective steel bollards for distribution equipment and manhole/handhole covers shall be bonded to the grounding conductor and grounded to separate grounding electrodes. Fence enclosures around or adjacent to substations shall be grounded to electrodes with flexible braid at 15 m (50 ft.) intervals, with bonding jumpers at gates and fence openings to provide metallic continuity. All grounding test points shall be accessible for verification.

A copper ground bus mounted 600 mm (24 in.) above finished floor, unless otherwise indicated and mounted on insulators 40 mm(1.5 in.) from the wall shall be provided as follows:

- Main electric room ground bus: 6 mm x 50 mm x 2400 mm (0.25 in x 2 in. x 96 in.) bus installed on one long access wall.
- Electrical closets/rooms: 6 mm x 50 mm x 600 mm (0.25 in x 2 in. x 24 in.) bus connected to the main electric room ground bus via a continuous #4/0 bare copper express ground riser. Provide a #4/0 bare copper ground conductor from each closet ground bus exothermically welded to vertical express ground riser, routed through stacked electric rooms to provide grounding connection between the closets.
- Main communication room ground bus: 6 mm x 50 mm x 600 mm (0.25 in x 2 in. x 24 in.) bus connected to the main electric room ground bus with a #2/0 insulated grounding conductor.
- Communication closets/rooms: 6 mm x 50 mm x 600 mm (0.25 in x 2 in. x 24 in.) bus connected to the main communication room with a #2/0 bare copper ground wire. A continuous #2/0 bare copper express ground riser from each closet ground bus vertically routed through stacked communication rooms shall provide grounding connection be-

tween the closets. Provide a #2/0 bare copper ground conductor from each closet ground bus exothermically welded to vertical express ground riser.

All underground connections shall be made using exothermic weld connectors and installed utilizing the appropriate tool as recommended by the manufacturer.

## B. Harmonics:

Where VFDs, electronic ballast, UPS, and a high concentration of computer loads relative to all other non-computer loads is anticipated, precautionary measures shall be taken. The following shall be provided where a large percentage (50% or more) of the load is of a non-linear nature.

- Full-size individual neutrals in branch circuits.
- Branch circuit panelboards with 200% neutrals.
- Transformers rated K-13 and 200% neutral from transformer to panel.
- Oversized neutrals for shared circuit homeruns to modular furniture.

In extreme cases where two high harmonic loads are approximately equal, a phase-shifting transformer shall shift the current of one load (feeder) relative to the other such that the harmonic currents cancel. This type of transformer is typically used to fix an existing problem and is difficult to apply during design unless specific information is known about the load.

## C. Transients:

ANSI/IEEE Standard C62.41 Category C3 TVSS protection shall minimally be provided at the service entrance (SE) when a lightning protection system is required. If very sensitive electronic equipment without UPS protection is present, the A/E shall consider providing a layered TVSS protection plan with category B3 TVSS protection at the downstream branch circuit panel.

## D. Lightning Protection:

New buildings at the NIH shall be evaluated for lightning protection based on the guidance provided by the latest NFPA Standard 780, Lightning Protection standard. Lightning protection shall be required where the NFPA 780 risk analysis indicates a moderate or higher risk. Lightning protection systems shall meet the most restrictive requirements among NFPA 780, LPI-175, and UL.

When a lightning protection system is to be installed on a new building, a ground girdle shall be provided encircling the entire building. Provide ground test wells at accessible locations.

All metallic objects such as pipes and conduits crossing the ground girdle shall be bonded to the ground girdle. The lightning protection system shall be bonded to the building ground system. Low buildings may be protected by the lightning protection installed on an adjacent higher building. The above listed standards indicate the zone of protection. New buildings requiring lightning protection shall receive a Master C Label from UL after the new lightning protection system is evaluated by UL and found to be acceptable.

If the outer envelope of an existing building is altered or modified, the lightning protection system shall be updated and the protection shall be verified. The vehicle for this process is a UL "Letter of Finding," rather than a review of the entire building. If a whole building review is required, a new Master C Label is issued, termed a "Reconditioned Master Label."

Lightning protection conductors shall be installed in nonmetallic conduit if routed inside buildings. The A/E shall determine the necessity of lightning protection modifications for temporary buildings and minor additions.

Properly sized surge protectors shall protect all medium voltage transformers, medium voltage motors, medium voltage distribution cables, and telephone and computer equipment.

# Section 10-7: Wiring methods and other requirements



## 10-7-00 Design Requirements

### A. Wiring:

Conductors shall be individual copper conductors in conduit with the exception of exposed conductors for lightning protection systems which may be aluminum or copper. Down conductors for lightning protection systems shall be copper. Wire insulation shall be color coded. Branch circuit conductors shall have colored insulation. Larger conductors shall be taped with the appropriate color tape for a minimum 150 mm (6 in.) starting from the termination. Each conductor of multi-conductor cable shall be color coded in the same manner as single conductors. Color coding shall be as shown in the following table for power conductors in the given voltage systems:

| Color Coding for Wire Insulation | | | |
|---|---|---|---|
| Power Conductor | 208/120 V | 480/277 V | 5/15 kV |
| Phase A | Black | Brown | Brown |
| Phase B | Red | Orange | Orange |
| Phase C | Blue | Yellow | Yellow |
| Neutral | White | Grey | Grey |
| Ground | Green | Green | Green |
| Isolated ground | Green with yellow tracer | Not Applicable | Not Applicable |

*Note: Parallel feeders shall be marked with the number of the feeder set on both ends of the conductors. Medium voltage cables shall be marked with feeder number.*

Color coding for control cables shall be of a uniform color provided permanent, numbered tape markers are placed on both ends and splice points of each conductor.

The minimum conductor size shall be #12 AWG, except #10 AWG for dedicated special purpose. Emergency circuits shall not be wired with normal power in the same raceway, even with dividers.

Branch circuits in operating rooms shall have type XHHW insulation and #10 AWG conductors. Isolated power branch circuits shall have conductors with orange and brown XHHW insulation to reduce leakage current.

Temporary construction wiring, except lighting, shall be installed for less than one year. All temporary wiring and lighting shall be removed by the end of construction. All temporary wiring to be installed for more than one year shall be installed per permanent wiring methods.

## B. Wiring Methods:

Conduit shall be classified by a nominal transition to metric.

| Conduit Size English to Metric Transition | | | |
|---|---|---|---|
| Inches | Millimeters | Inches | Millimeters |
| ½ | 16 | 2½ | 63 |
| ¾ | 21 | 3 | 78 |
| 1 | 27 | 3½ | 91 |
| 1¼ | 35 | 4 | 103 |
| 1½ | 41 | 5 | 129 |
| 2 | 53 | 6 | 155 |

Conduit shall be metallic to provide a redundant ground path. PVC or aluminum conduit is not acceptable, except as noted. PVC conduit may be used in underground applications and shall be used in concrete ductbanks.

All service and feeder conduit routing shall be clearly shown on the contract drawings. Homerun with panel designation and circuit numbers shall be provided for circuiting. All switch legs and circuit continuations shall be indicated on the contract drawings. The contract drawings shall clearly indicate where conduits are to be installed in an exposed manner and where they are to be installed in a concealed manner.

The minimum conduit size for power cables shall be 21 mm (3/4 in.). Conduit fill shall be limited to three circuits or six current carrying conductors.

The minimum conduit size for telecommunication cables shall be 27 mm (1 in.).

Metal clad (MC) cable is acceptable for power (receptacle, wiring devices and lighting) use in administrative areas and public spaces. MC cable is not allowed in laboratory or vivarium areas. Where allowed, MC cable is not allowed as the final homerun to panel.

Surface-mounted conduit in wash down areas shall be intermediate metal conduit (IMC) or rigid galvanized steel (RGS) with threaded couplings. Flexible metal conduit shall be used for lighting fixture connections (whips) and for connections to equipment subject to vibration, noise transmission, or movement. Lighting fixture connections shall be made with 1.2 m (4 ft.) minimum and 1.8 m (6 ft.) maximum lengths of flexible metal conduit. Liquid-tight, flexible metal conduit shall be used for motor connections and under-cabinet lighting. Raceway systems shall be provided for all wiring.

Boxes for interior electrical systems shall be hot-dipped galvanized steel or malleable iron and shall be compatible with the raceway system.

Cast boxes with external hub and gasketed device cover plates shall be provided in vivarium spaces. Wiring shall be surrounded with a 25 mm (1 in.) barrier of silicone caulking within the device box hub. Provide a continuous bead of silicone caulk around the device cover plate and the adjacent surface. If device boxes are surface mounted on RGS conduit, both sides shall be sealed to adjacent surfaces with a continuous bead of silicone caulk.

See Architectural Chapter 4 Exhibit X4-2-A “Joint Sealants and Caulking” for additional information.

## B.1 Conduit (Within Buildings):

All conduits shall be installed parallel or perpendicular to the building features, except for conduit run in or under the slab. Conduit shall not be installed in the slab on grade. Fittings for metallic conduits shall be compression type steel or malleable iron. Conduit shall not be attached to box covers, except for 16 mm ( 1/2 in) or smaller flexible conduit terminated on a flush mounted box cover. All service and feeder conduits shall be marked with machine made labels every 15 m (50 ft.) indicating their use. All conduits shall be supported with approved devices (tie wire is not acceptable) independent of other systems and equipment. Conduit shall not be run exposed on top of roof surfaces.

Conduit shall be installed as specified below, and per code. RGS conduit with threaded fittings shall be used in the following locations:

- Elevator shafts, exterior areas, and areas prone to physical damage.
- Where exposed within 2.4 m (10 ft.) of the finished floor level and a point above 2.4 m (10 ft.) past the vertical to horizontal transition.
- Where exposed in animal research facilities, with 20 mm (3/4 in.) standoffs or sealed on both sides to adjacent surfaces with a continuous bead of silicone caulk.
- Where conduits larger than 103 mm (4 in.) are required.

PVC schedule 40 nonmetallic conduit shall be used in the following locations:

- Below concrete floor slab on grade.
- Within concrete walls or within floors above grade.

Where elbows are terminated above slab, provide RGS elbows. PVC conduit stubbed out of floors shall transition to RGS raceway prior to the point where the conduit is exposed. RGS conduit may be substituted for PVC schedule 40.

EMT may be used where allowed by code in all other interior spaces.

Non-ferrous conduit or aluminum conduit shall be used in magnetic field, (e.g., MRI, NMR) areas. Possible restrictions may be in place for aluminum conduit due to radio frequency (RF) interference.

Dedicated cable tray may be used for communications wiring or for racking medium-voltage cabling, subject to NIH approval.

## B.2 Conduit (Underground):

All underground conduits shall be PVC or RGS. Conduits shall be concrete encased when buried beneath roadways or when used for medium voltage applications. Minimum size for conduits used for medium voltage shall be 129 mm (5 in.). Direct buried conduit is acceptable for electrical systems rated 600 V and below. Rigid steel may be direct buried if coated with asphalt paint or PVC.

PVC electrical conduit for underground runs shall be a minimum of type EB if concrete encased, or schedule 40 if direct buried. All empty ducts shall be provided with a minimum 4 mm (0.15 in) diameter nylon pull wire for pulling future cables. All empty ducts shall be

sealed to prevent water seepage into the handhole or manhole. Ducts shall be sloped to prevent water drainage into the building.

Prior to pulling cable into any conduit, the conduit shall be cleaned with a wire brush 16 mm (1/2 in.) larger than the duct and rodded with a mandrel 8 mm (0.3 in.) smaller than the duct to test the integrity of the duct.

Direct burial of power and signal cables is not permitted. Where an existing direct-buried street lighting circuit is being extended one or two poles, the circuit may be direct-buried. Where new circuits, street lighting or otherwise, are installed underground, they shall be placed in PVC schedule 40 or PVC-coated RGS conduit. Where the cable is direct-buried, it shall be protected the full length by 25 mm x 150 mm (1 in. x 6 in.) nominal pressure treated lumber, 150 mm (6 in) above the cable. The cable shall be buried 750 mm (30 in.) below grade. For all buried conduits, metallic foil-backed plastic cable marking tape 150 mm (6 in.) wide shall be installed 300 mm (12 in.) below grade above the conduit run. The plastic marking tape shall be red or yellow and read “CAUTION: BURIED ELECTRIC LINE”. The plastic conduit shall be placed minimum 600 mm (24 in.) below grade.

## C. Wiring Devices:

Duplex receptacles shall be minimum specification grade rated at 20 A, 125 V, and be polarized parallel-blade-type with ground and NEMA 5-20R configuration. The mounting brackets shall be extra heavy, and the terminals shall be copper alloy. The receptacle shall be side wired. Cover plates for building interior receptacles, switches, and boxes shall be stainless steel, brushed aluminum or hospital grade impact-resistant nylon. Cover plates for cast boxes shall be gasketed and weatherproof. Receptacles shall be identified according to normal power, emergency power, or computer power. Tamperproof receptacles, where required, shall be NEMA 5-20R safety type that operates with either a two or three-bladed plug.

Toggle switches used to control lighting shall be specification grade rated for use on 120 V and 277 V circuits and shall be rated for a minimum of 20 A. Occupancy sensor switches shall be the dual technology type combining both ultrasonic (US) and passive infrared sensing (PIR). These switches shall be used in offices, rest rooms, and conference rooms. For mechanical rooms and service areas, smart switches with timer controls shall be provided.

## D. Surface Metal Raceway:

Steel, stainless steel or aluminum modular surface metal raceway (SMR) shall be used when an area is classified as a dry location. SMRs shall be metallic; plastic is not acceptable. SMRs shall not be used in cold, freezer or warm environmental rooms.

SMR shall be used for providing circuits in laboratory areas allowing for future flexibility. Either a 60A, 3 phase, 4 wire system with raceway integral circuit breakers or traditional local panelboards and individual receptacle circuits may be provided. When SMR with integral circuit breakers is used, taps in raceway shall be via three-ganged, 20A single pole circuit breakers. Receptacles shall be mounted 600mm (2 ft.) on center, minimum, alternating circuits and phase balanced with no more than four receptacles per circuit. Dedicated circuits for specialty equipment shall be run in separate conduits and not through the raceway system.

The required nominal dimensions shall be:

| Surface Metal Raceway Nominal Dimensions | |
|---|---|
| Raceway Type | Dimensions |
| Single channel | 70 mm x 37 mm (2.75 in x 1.5 in.) |
| Two channel | 121 mm x 44 mm (4.75 in. x 1.75 in) |
| Two channel | 121 mm x 90 mm (4.75 in. x 3.5 in.) |

Normal power circuits and communication cabling are allowable in the same SMR when provided with dividers. Even with a divider, emergency power circuit conductors shall not be run with normal power circuits or communication cabling in the same SMR.

## E. Other Requirements:

Receptacles shall be installed so that the ground prong is mounted in the up position unless mounted 1.57 m (60 in) above finished floor or higher. Where isolated ground circuits are required, an isolated ground conductor shall be installed with the branch circuit. Refer to Section 10-6 “Power Quality” for panelboard-isolated ground bus requirements.

- Offices shall have a minimum of one general purpose (ivory) receptacle per wall.
- Receptacles for computers and printers shall be provided with engraved cover plates or nameplates riveted to the cover plate.
- Personal computers (PCs) shall be limited to three per 20 A circuits including prewired modular furniture.
- Laser printers shall be limited to two per 20 A circuits including pre-wired furniture.
- Computer and laser printer receptacles shall not be connected to the same circuit nor to the general (ivory) receptacle circuits. These circuits shall be provided with dedicated neutral conductors.

- General-purpose receptacles shall have a design load of 180 VA each with a maximum of six receptacles connected to a circuit.
- All receptacles shall be indicated by NEMA configuration.
- A 20 A duplex receptacle shall be mounted within 7.6 (25 ft.) of and on the same level as any electrically operated equipment on rooftops, in attics, and in crawl spaces. The receptacle shall be on a separate circuit from that serving the equipment.
- GFCI protected receptacles shall be provided within 1 m. (3 ft.) of laboratory and vivarium sinks. This does not include cup sinks or receptacles dedicated near sink locations for local water polishing units. GFCI receptacles shall not be wired to protect downstream receptacles except in indoor installations where the downstream receptacles are in the same room.
- GFCI type receptacles shall be provided for outdoor applications.
- GFCI type receptacles shall be provided in animal facility rooms subject to hose down cleaning methods.
- Receptacles for power ventilated racks shall be twist-lock NEMA L5-20R or at program discretion NEMA 5-20R hospital grade.
- In restrooms, for automatic flush valves and paper towel dispenser connections provide a 120V, 20A dedicated circuit for each group of fixtures.

## F. Demolition:

If the work requires that wiring be removed from conduit that is not embedded in concrete and if that conduit is not scheduled for reuse on the same project, then the conduit is to be removed. The following exceptions apply:

- The lighting switch leg conduit connected to the first outlet box if the wall containing the switch is to remain.
- Vertical conduit connected to the first outlet box at panelboard if the panelboard is of the recessed type.

If the work requires that the wiring be removed from an embedded-in-concrete conduit and if that conduit is not scheduled to be reused, the conduit shall be abandoned in place. Conduit that enters the slab from below shall be cut after the wires are removed, as close to the slab as practical but with not more than 21 mm (3/4 in.) protruding. Conduit that enters the slab from above shall have the floor material removed so that the conduit can be cut with a cold chisel at least 6 mm (1/4 in.) below the slab elevation; then the conduit and enlarged opening shall be sealed with nonshrinking grout and the slab surface finished flat and true.

## G. Disconnects:

All disconnect switches shall be heavy duty type. Disconnect switches shall have a minimum clear mounting height of 460 mm (18 in.) above grade outdoors and 1,000 mm (42 in.) above finished floor in interior spaces.

## H. Electric Heat:

Electric heating shall not be used to heat NIH buildings. Equipment rooms may utilize up to 3 kW electric heat if hydronic heat is not available.

## I. Nameplates:

All electrical equipment, shall have nameplates identifying the name of the piece of equipment or the name of the equipment served (e.g. disconnects, starters, etc.). Nameplates shall be laminated phenolic legend plates with white letters on black surround for normal power and white on red surround for emergency power. Nameplates shall have minimum 7 mm (1/4 in.) high letters for small equipment and disconnects, 13 mm (1/2 in.) high for medium size wall mounted equipment such as panel boards and individual size 2 starters and above, and 50 mm (2 in.) high for freestanding equipment such as large panelboards, switchgear, and liquid filled transformers. The nameplates shall be attached with stainless steel screws. To identify electrical source of the equipment, under the equipment name in smaller letters, the words “FED FROM” followed by the source panel or riser name shall be included.

## J. Circuit Identification:

All circuits shall be identified with panelboard source and circuit number. Wiring devices, including light switches, shall be provided with laminated labels on device cover plates.

## K. Monitoring Systems:

Monitoring and alarm notification shall be provided in laboratories and animal research facilities via BAS or a stand alone system. A cost analysis shall be performed to justify use of a BAS or stand alone system. The monitoring system shall have the ability to generate reports without proprietary software.

# Section 10-8: Lighting

10-8- 00 Design Requirements
10 Design Guidance
20 Design Information (Reserved)
30 Design Document Requirements (Reserved)

## 10-8-00 Design Requirements

Although illumination levels are considered the primary lighting design bench-mark, visibility factors are of equal importance especially in environments where difficult visual tasks are being performed. Visibility factors include:

a. Uniformity: The lighting system shall provide uniform illumination levels across the work plane to reduce the eyes adaptive process and eye fatigue.
b. Glare: Direct glare from poorly shielded light fixtures reduces visibility. Reflected glare from glossy surfaces can be as visually disabling as direct glare.
c. Shadows: Minimizing shadows improves visibility and reduce eye fatigue.
d. Surface brightness: Balancing brightness of work plane, walls and ceiling enhances visibility and creates a more comfortable visual environment.
e. Vertical Surface Illumination: The lighting system shall provide adequate illumination on vertical surfaces such as case work and cages.

Lighting requirements shall follow the IESNA Lighting Handbook except as noted herein.

A lighting fixture schedule on drawings, identifying at least three manufacturers, catalog numbers, fixture voltage, lamp types, number of lamps, fixture depths, installation methods, description of fixtures, and remarks shall be provided for each fixture type identified as approved equals.

One fixture, minimum, with self-contained emergency battery pack or emergency battery ballast, shall be provided in all electrical vaults, switchgear rooms, major electrical distribution rooms and at all locations of automatic transfer switches. When emergency power is available, 50% of the fixtures in these rooms shall be connected to emergency power.

# 10-8-10 Design Guidance

## A. Lamps:

Fluorescent lamps shall be 1.2 m (4 ft.), 28 or 32 W F32-T8 or 600 mm (2 ft.), 17W F17-T8. All lamps shall have minimum color temperature of 3500 K, color rendering index (CRI) of 77, and rated average life of 20,000 hours. U type lamps are not permitted. Compact fluorescent lamps shall be made with 13 mm diameter tubes, with minimum color temperature of 3500K, CRI of 82, and rated average life of 10,000 hours.

Fluorescent lamps are recommended in all but the most critical color-rendering applications. In those few specific applications, incandescent lamps may be utilized. Specify halogen infrared (HIR) lamps providing lumen output of 1,150 and lamp life of 3,000 hours.

Metal Halide (MH) lamps shall have a minimum color temperature of 3,200 K, rated life of 9,000 to 15,000 hours depending on the wattage, and a minimum CRI of 65.

High Pressure Sodium (HPS) lamps shall have a minimum color temperature of 1900 K, rated life of 16,000 to 24,000 hours depending on the wattage, and a minimum CRI of 22.

Lighting fixtures with specialty lamps with less than 3,000 hours lamp life shall not be specified.

## B. Fluorescent Lamp Ballast:

Ballast shall be solid-state electronic. Ballast shall be UL listed, Class P thermal rating, and Class A sound rating per UL 935-84; and certified as follows by lighting Electronic Testing Laboratory (ETL) or Underwriter's Laboratories (UL), and labeled by Certified Ballast Manufacturers Association (CBM). Ballast shall have an operating frequency of 20 kHz or greater. Ballast shall contain no polychlorinated biphenyl (PCB). Light regulation shall be ±10% with nominal ±10% voltage variation. Lamps shall be operated in instant start mode. Ballast shall be designed to withstand transients described in IEEE Standard 587, Category A. Ballast temperature rise shall not exceed 25 °C over 40 °C ambient. Ballast shall meet Federal Communications Commission (FCC) regulations, Part 18. Ballast shall have a minimum 5 year warranty. Ballasts shall have less than 10% total harmonic distortion. Remote ballasts shall be considered in magnetic, radio frequency and electrophysiology areas. The A/E shall take low THD ballast inrush current into consideration when calculating lighting circuit loads.

## C. Exterior Lighting:

Exterior lighting requirements shall be coordinated with the Project Officer on a per project basis. See Civil Engineering and Site Development Chapter 3 Section 3-4-10-A "Landscape Lighting Design Considerations" for exterior light fixture requirements. The following types of light sources shall be used where noted:

| Exterior Light Source Type | |
|---|---|
| Area | Light Source |
| Animal and Food Service Loading Docks | HPS |
| Architectural lighting | MH |
| Landscape lighting | MH or HPS |
| Loading docks | MH |
| Parking garages | MH |
| Site lighting, roadways, sidewalks | MH |

The A/E shall minimize light pollution or the intrusion of NIH light on bordering neighbors. "House side shields" on fixtures or light fixtures with good "cut-off" optics for glare control shall be utilized near NIH property lines. The placement of lighting poles near property lines shall be avoided. Security illumination shall be provided.

Street lighting shall utilize fixtures compatible with the existing NIH campus lighting standards, mounted 8 m (25 ft.) above the pavement maximum with a 175 W MH lamp. The mounting arm shall be 1.8 m (6 ft.) long.

Street lighting units shall be placed 30 m (100 ft.) to 35 m (115 ft.) apart along the two-lane roads on the NIH Bethesda campus, providing a minimum average maintained lighting level of 50 lux (5 FC) on the roadway. The walkway lighting units shall be placed 25 m (80 ft.) to 30 m (100 ft.) apart, providing a minimum average maintained lighting level of 10 lux (1 FC). Various specific locations may require reduced spacing if they are high-accident areas or for security reasons. The A/E shall coordinate with the Project Officer for such areas.

Street lighting circuits shall be controlled at the point of origin by a photoelectric cell mounted on the side of the building where the circuit originates. A switch shall be provided to bypass the photocell so that the circuit can be energized during the day for trouble shooting purposes. Site lighting circuits shall use minimum #6 AWG wire in minimum 41 mm (1.5 in.) PVC conduit. The maximum circuit breaker size protecting site lighting circuits shall be 30 A.

Outdoor lighting circuits shall not have underground splices or tee splices. Splices shall only occur in accessible locations in light pole bases.

Site lighting circuit voltages of existing circuits shall be obtained from the Project Officer.

Animal loading docks and food service loading docks shall use HPS lighting located away from doors. Loading docks shall be provided with 120 V source(s) for bug "zapper" fixtures.

Where contactors are used, they shall be mechanically held.

The protective circuit breakers shall be single phase to preclude a total outage of light in any one area. Pole mounted lighting fixtures and interior pole wiring shall be protected by in-line fuse holders located within the pole base or transformer housing.

## D. Light Poles:

Roadway lighting poles shall have breakaway bases; poles for parking lots shall be protected by mounting on poured concrete bases, and have adjusting leveling nuts. Mounting bolts and adjusting leveling nuts shall have trim cover. Where poles are placed immediately at the edge of a parking lot or other areas where automobile bumpers may come in contact, the pole shall be mounted on a 1 m (40 in.) high concrete base for protection.

Light pole height for parking area shall be limited to 8 m (25 ft.). Site lighting poles shall have a 75 mm x 25 mm (3 in. x 1 in.) aluminum tag riveted to the pole. The tag shall clearly identify the building, panel, and circuit number where the service is derived.

For all outdoor lighting poles, a 3 m (10 ft.) long, 19 mm (3/4 in.) diameter copper-clad ground rod shall be placed in the foundation, and all metallic components shall be grounded to the rod, including metal standard, the ground wire pulled in with the power circuit, and an equipment ground wire to the luminaire. All lighting poles shall be grounded.

## E. Interior Lighting:

The zonal cavity method shall be used for calculating the design light levels for uniform layouts with standard light fixtures. The point-by-point method shall be used for calculating the design light levels for unique lighting fixture applications or where asymmetrical lighting layout is utilized. A maintenance factor of 75% shall be used.

Fluorescent light fixtures with direct lighting shall be directly above and parallel to the front edge of the laboratory bench to prevent shadows. Direct/indirect fixtures may also be used.

Care shall be exercised in modeling laboratories for illumination calculations, as shelving shall be assumed as fully loaded, solid surfaces, similar to a wall, with minimal, if any, contribution from adjacent light fixtures. Task lighting shall not be considered in lighting calculations.

Storage areas, mechanical equipment areas and rooms with exposed/finished high ceilings shall use fluorescent or HID lamps, depending on the size of the area and height of the ceiling. Use of incandescent lighting is subject to NIH approval. Where HID fixtures are used for interior illumination, all fixtures shall be equipped with instant restrike ballast.

Recessed fluorescent lighting fixtures shall be supported from the building structure at a minimum of two diagonal corners independent of the ceiling construction. Steel wire shall be minimum 3.5 mm (0.1 in.). Lighting fixture pendants shall be minimum 13 mm (0.5 in.) diameter stems with swivel mounts. Industrial fluorescent lighting fixtures shall have a wire guard over the lamps. Under-shelf mounted light fixtures shall have plastic lenses over the lamps.

Where closed circuit television (CCTV) cameras are present, occupancy sensors shall not be the sole lighting control. One lighting fixture within CCTV coverage area shall be controlled by a local key switch, at a minimum.

Following table lists the light level requirements for various spaces.

| Lighting Levels | |
|---|---|
| Function/Space | Lighting Levels in lux (FC) |
| Offices | 430-650 (40-60) |
| Corridors | 325-430 (30 – 40) |
| Stairwells | 220-325 (20 – 30) |
| General storage | 220-325 (20 - 30) |
| Mechanical/electrical room | 325-540 (30 - 50) |
| Laboratories and laboratory support areas | 800-1075 (75 – 100) |
| Laboratory Equipment Rooms | 325-540 (30 – 50) |
| MPW waste holding | 220 - 325 (20 – 30) |
| Imaging laboratories | 550 (50) |

## F. Animal Research Facility (Vivarium) Lighting and Controls:

Animal holding room lighting control shall be provided by a programmable lighting control system, either using the BAS or a stand alone system (which already may be used for flushing operation of animal watering system), which ever is more cost effective. The system selected shall provide a terminal for user control and adjustment of lighting cycles within the vivarium supervisor's office, or at another location within the vivarium as directed by the user. The control system shall be provided with necessary integral battery backup to provide uninterruptible service during the time delay for the transfer from normal to diesel emergency power. Local engineered override switches shall also be required to function as indicated under each species lighting operation. Confirm if dimming control to simulate dusk and dawn circadian cycles is required.

For small new facilities and small renovations, the A/E shall also consider the use of individual astronomical timers as a cost effective means of providing the required lighting control. Local engineered override capability is required.

All lighting fixtures within animal holding rooms shall be on normal building power. Though not required for AAALAC accreditation, lighting shall be directed to be on diesel emergency power if required by the veterinary program direction.

UL listed, damp location, factory sealed and gasketed fluorescent lighting fixtures with three T-8 lamps per fixture, in sufficient quantities per room to achieve the required illumination levels shall be provided in small animal and rodent holding rooms.

UL listed, wet location, factory sealed and gasketed fluorescent lighting fixtures capable of with-standing a hose directed spray (minimum 85 PSI or minimum IP65 rated) with three T-8 lamps per fixture in sufficient quantities per room to achieve the required illumination levels shall be provided in large animal and non-human primate holding rooms.

Animal holding rooms that are designed with flexibility to handle either species shall incorporate the lighting fixtures required for large animal and non-human primates, thereby only requiring reprogramming of user lighting illumination levels and circadian cycle changes as required in the future.

Lighting fixtures shall be recessed, ceiling mounted. Lighting fixtures shall be provided with number of ballasts as required for specific operations indicated. Feed-through and/or tandem wiring of fixtures shall not be permitted.

Though not required for AAALAC accreditation, all holding rooms may require monitoring to proof and report on lighting cycle function within each room if required by the veterinary program direction. Monitoring requirements such as sensor type, location and proofing of on-off or illumination level functions per holding room shall be determined on a per project basis.

Lighting operation in animal holding rooms shall be based on species. See the following table for average lighting levels in various areas of an animal facility.

| Lighting Levels | |
|---|---|
| Function/Space | Lighting Levels in lux (FC) |
| Animal facilities | 270-800 (25 – 75) multi-level |
| Aquatic Facilities | 540 – 800 (50 - 75) Note 1 |
| Animal Facility Surgery rooms | 1075 (100) |
| Non-human primate holding ante rooms | 540 (50) |
| Procedure, Necropsy and treatment rooms | 1075 (100) |
| Animal Facility Surgery table area | 2200 (200) |
| Storage room | 220 - 325 (20 – 30) |
| Locker and Toilet rooms | 220 - 325 (20 – 30) |
| General storage | 220-325 (20 – 30) |
| Offices and Administration area | 430 – 650 (40 – 60) |
| Cage wash areas | 750 (70) |
| Feed and bedding areas, autoclave and cage wash service areas | 220 - 325 (20 – 30) |
| Receiving/decontamination area | 220 - 325 (20 – 30) |
| Animal Facility corridors | 430 – 540(40 – 50) |
| MPW waste holding | 220 - 325 (20 – 30) |

*Note: 1. Possible dimming to simulate dusk and dawn cycles*

Lighting Operation for Large Animals and Non-Human Primates: Diurnal lighting cycle control typically provides a lighting cycle of 12 hours “on” and 12 hours “off”, but shall be adjustable to change either cycle duration, or provide for multiple cycles in a single day at user discretion and adjustment. The “on” cycle shall provide an illumination level between 375-540 lux (35 – 50 FC), while operating two lamps per fixture. The “off” cycle requires all three lamps to be extinguished.

One local engineered override switch shall be required outside each holding room door to provide a caretaker cycle which would bring on the two lamps of the “on” cycle, plus one additional lamp to achieve an 800 lux (75 FC) level within each room.

For large animals and non-human primates one lighting fixture per holding room shall also be provided with a self-testing emergency battery ballast (non-audible, visual indication only) to provide this one fixture within room with some continuous illumination in the event of a normal power failure. If the vivarium lighting is provided with an emergency power source, this shall span the allowable time delay for the transfer from normal to diesel emergency power for personnel safety. This ballast shall minimally operate a single lamp (not to exceed two lamps) per single fixture and shall operate under the same diurnal controls as normal power operation, i.e. the ballasts shall illuminate lamp(s) on during the programmed “on” diurnal cycle only, and not illuminate any lamps if a power outage occurs during the programmed “off” cycle. When either diesel emergency power is available, or normal power is restored, the emergency battery ballasts shall revert back to their standby operation. The same shall apply for small animal and rodents, if required for species room flexibility, but shall be determined on a per project basis as it is not typically required.

Lighting Operation for Small Animal and Rodents: Diurnal lighting cycle control typically provides a lighting cycle of 12 hours “on” and 12 hours “off”, but shall be adjustable to be able to change either cycle duration, or provide for multiple cycles in a single day at user discretion and adjustment. The “on” cycle shall provide an illumination level between 270-325 lux (25 – 30 FC), while operating one lamp per fixture. The “off” cycle requires all lamps to be extinguished.

One local engineered override switch shall be required outside each holding room door to provide a caretaker cycle which would bring on the single lamp of the “on” cycle, plus two additional lamps to achieve an 800 lux (75 FC) level within each room

For both lighting operation scenarios, this engineered override switch shall circumvent the programmable lighting panel controls diurnal cycling for a user adjustable time period of between 0 to 60 minutes, and then have the programmable lighting control revert back to its normal diurnal cycle as previously programmed. A second manual switch operation is not required to go back to the normal diurnal cycle operation. A second manual operation shall not change or increase the timed override until after the override cycle has timed out, but it is acceptable for the second manual over ride switch operation to directly force the programmable lighting controller to go back to the normal diurnal cycle operation immediately, as long as this is a standard operational feature.

Though not required for AAALAC accreditation, an additional single lamp lighting fixture may be required for out-of-diurnal-cycle entry, with same characteristics, power requirements and mounting as required based on holding room applications, if required by the veterinary program direction. The single lamp shall be provided with a red (or possibly other color) sleeve, or filmed lens as directed by the veterinary program direction. The actual user shall provide information for sleeve or lens film color for filtering lighting spectrum frequencies as required by programmatic needs. This fixture shall be controlled by single pole switching control.

Other room types located within an animal research facility shall be provided with the following functional lighting requirements:

- Autoclave service area: One two lamp lighting fixture shall be UL damp, factory sealed and gasketed type, on normal or emergency power with single pole switching control.
- Quarantine and cubicle holding rooms: Same requirements listed under large animal and non-human primates; and small animal and rodents above.
- Non-human primate holding ante rooms: All lighting fixtures shall be UL wet, factory sealed and gasketed type, with one fixture on diesel emergency power operated by a single pole switched light, and any others on normal power with single pole switching control.
- ABSL2 procedure, necropsy and treatment rooms: All lighting fixtures shall be UL damp, factory sealed and gasketed type, with one fixture on diesel emergency power operated as an unswitched night light, and any others on normal power with single pole switching control.
- Vivarium surgery rooms: All lighting fixtures shall be UL damp, factory sealed and gasketed type, with 50% of the fixtures on normal power and the remaining fixtures on emergency power with single pole toggle switches. At least one fixture on both normal and emergency power shall be provided with a self testing emergency battery ballast (non-audible, visual indication only). Task and exam lights shall be on emergency power.
- Storage room: All lighting fixtures shall be UL damp, factory sealed and gasketed type fixtures, on normal power with single pole or occupancy sensor switching control.
- Locker and toilet rooms: All lighting fixtures shall be UL damp, factory sealed and gasketed type fixtures, with at least one fixture on diesel emergency power operated as an unswitched night light, and any others on normal power with single pole or occupancy sensor switching control. Any shower lighting fixtures shall be UL wet, factory sealed and gasketed on single pole switching control.
- Offices and administration areas (not including facility supervisor's office): All lighting fixtures shall be UL damp, factory sealed and gasketed type fixtures, on normal power with single pole or occupancy sensor switching control, with the exception of code re-

quired emergency egress lighting in the common egress path of travel for the suite, operated unswitched as a night light. • Facility supervisor's office: All lighting fixtures shall be UL damp, factory sealed and gasketed type fixtures, with at least one fixture on diesel emergency power operated by a single pole switch, and any others on normal power with single pole or occupancy sensor switching control.

- Cage wash areas (except for service areas): All lighting fixtures shall be UL wet location, factory sealed and gasketed type fixtures capable of withstanding a hose directed spray (minimum 85 PSI or minimum IP65 rated), with a minimum of one fixture on diesel emergency power per area operated as an unswitched night light, and any others on normal power with single pole switching control.
- Feed and bedding, autoclave service, and cage wash service areas: All lighting fixtures shall be UL damp, factory sealed and gasketed type, on normal power with single pole switching control.
- Receiving/decontamination area: All lighting fixtures shall be UL damp, factory sealed and gasketed type, with one fixture on diesel emergency power operated as an unswitched night light, and any others on normal power with single pole or occupancy sensor switching control.
- Corridors: All lighting fixtures shall be UL damp, factory sealed and gasketed type, with egress fixture as required on diesel emergency power operated as unswitched night lights, and any others on normal power with single pole or occupancy sensor switching control.
- MPW waste holding: Environmental box with vaporproof lighting provided by box manufacturer, external pilot light single pole switch control, and control panel (including refrigeration system) shall be on diesel emergency power.

# Section 10-9: BSL3 & ABSL3 Biocontainment



## 10-9-00 Design Requirements

### A. BSL3 Laboratory Power Requirements:

### A.1 Electrical Service Requirements:

On the main NIH Bethesda campus, electric service shall consist of multiple electrical service feeders in a spot network configuration. For facilities located elsewhere, the minimum requirements are two independent dedicated utility services, physically separated in different duct banks and different manholes. By being independent, each service shall be fed by a different primary substation or one double ended utility substation which is fed by two independent lines. By being dedicated, no other user shall share the lines with the facility. The preference for the utility services is underground lines. Overhead lines shall only be used within the secure perimeter of the facility. Each required service to the facility shall be sized to handle 100% of the design load (2N redundancy).

For facilities outside of NIH Bethesda, onsite medium voltage distribution, including Medium Voltage (MV) / Low Voltage (LV) transformers, shall be customer owned, rather than utility owned, enabling the owner to have greater control in receiving appropriately sized best quality equipment installed which will aid in maintenance. In addition, distribution equipment, such as MV switches and transformers, shall be located in more secure environments. Often, medium voltage interrupter switches and transformers are incorporated with the low voltage gear into a double-ended secondary unit substation, but this is not the only acceptable arrangement. If customer owned distribution is not possible, coordination with the utility shall occur to ensure they provide the distribution system that meets the facilities full requirements, which may considerably exceed the utility's own engineering and construction standards. The MV/LV transformer (or set of transformers) for each service shall be sized for 100% of the total design load of the facility (2N redundancy).

For BSL3 projects with a low voltage arrangement of double ended switchgear, an automatic main-tie-main breaker configuration is also acceptable, where if one utility main is lost, the tie can close and allow the other main to supply the entire load. The switchgear shall be

metal clad compartmentalized type with each breaker capable of being racked out and replaced with the switchgear energized.

Down stream distribution from switchgear for critical areas, such as mechanical support rooms with redundant motors in each set, shall consist of pairs of distribution switchboards/panel boards, each fed from a separate side of the switchgear, to supply approximately half of each set of motors. This would include supplying packaged units with multiple motors with separate feeders for each motor, where possible.

## A.2 Reliability:

The A/E shall evaluate and minimize single points of failure for all projects.

## A.3 Standby Power Requirements:

Following loads shall be connected to the emergency system in addition to the loads listed in Section 10-5 “Emergency Power” required to be connected to the emergency system:

- Boilers.
- Chemical feed pumps.
- Chilled water pumps.
- Chillers.
- Condensate pumps.
- Condenser pumps.
- Controls air compressors.
- Cooling towers.
- Critical support fan coil units.
- Domestic water booster pumps.
- Receptacles serving selected equipment.
- Environmental rooms.
- General lighting.
- Hot water pumps.
- Incubators.
- Laboratory air compressors.
- Mechanical controls.
- Sterilizers.
- Supplemental heating/cooling.
- Water heaters.

The following loads are recommended to be connected to the generator power and shall be determined on a per program basis:

- Freezers/Refrigerators/Environmental rooms, other than high value specimen units.
- Distilled water systems.
- General laboratory receptacles.
- Heat reclaim systems.
- Imaging equipment.
- Task lighting.
- Vacuum pumps.

Consider providing 100% generator back-up for facilities where the required loads encompass the majority of the entire facility. A local generator dedicated to the facility shall be provided. Emergency/standby power provided by a remote generator farm (with redundant generators) may also be acceptable.

A load bank (including a connection point suitable for use for a portable generator) shall be required for BSL3 facilities. Refer to Section 10-5 Paragraph A "Generator," for requirements.

## A.4 Uninterruptible Power Supply (UPS)

Requirements: A central UPS system or a number of local UPSs may be required to back-up all building wide low voltage systems that are essential for containment operation as well as critical BSL3/ABSL3 specific loads. An economic analysis shall be performed to select the appropriate UPS system. The following systems are recommended to be connected to the UPS:

- Building automation systems (BAS).
- Select light fixtures in lieu of emergency battery packs.
- Communications and PA systems.
- Fire alarm systems.
- Lab equipment monitoring systems.
- Mechanical controls.
- Security, CCTV and access control systems.

The central UPS shall be of the double-conversion on-line type. Wet cell type batteries are recommended.

# B. BSL3 Laboratory Lighting Requirements:

## B.1 General Lighting Criteria:

Multiple aspects shall be considered in designing lighting systems for BSL3 areas including a review of these factors as follows: Also refer to Section 10-8 “Lighting” for additional guidance.

## B.2 Containment:

The lighting systems shall be designed to ensure biohazards are contained within the area. Lighting fixtures shall be easily opened to permit full decontamination.

## B.3 Illumination:

The lighting system shall provide proper lighting levels for performing visual tasks within the containment environment.

## B.4 Visibility:

Although illumination levels are considered the primary lighting design bench mark, visibility factors are of equal importance especially in containment environments where difficult visual tasks are being performed. See Section 10-8 “Lighting” for visibility factors.

## B.5 BSL3 Laboratory Lighting Fixtures:

Lighting systems shall be designed with the containment barrier at the outlet box. Refer to Paragraph C.7 “Boxes for all systems” for outlet box requirements. These areas require strict moisture and vermin control. Surface mounted, fully sealed, enclosed and gasketed fluorescent fixtures shall be used. Fixtures shall be equipped with stainless steel housings, glass or heavy duty acrylic prismatic lens and stainless steel door with tool less fasteners. Fixtures shall be UL listed for damp location and provided with a continuous bead of sealant around its perimeter to seal housing to ceiling. Lighting fixtures may be pendant mounted only if no ceiling is provided. Pendant mounted lighting fixtures shall be fully sealed and gasketed with same features as surface mounted fixtures. 50% of light fixtures shall be normal power and 50% on emergency power.

## B.6 Emergency Lighting:

During power failures, occupants in containment rooms shall never be in complete darkness. At least one lighting fixture per room in BSL3 laboratory areas shall be provided with a self-testing emergency battery ballast (visual indication only) to provide this one fixture within room with some continuous illumination in the event of a normal power failure. Lighting fixtures with emergency ballasts shall be connected to unswitched generator powered emergency circuits.

## B.7 Lighting Design Criteria by Area:

Lighting levels for areas in within BSL3 containment are listed in the following table.

| Lighting Levels | |
|---|---|
| Function/Space | Lighting Levels in lux (FC) |
| Laboratories and Lab support | 800 - 1075 (75 - 100) |
| Equipment rooms | 550 - 750 (50 - 75) |
| Imaging laboratories | 550 (50) |

Lighting requirements for the various types of areas within the BSL3 containment environment are as follows:

Laboratories and Lab Support Rooms: Light fixtures shall be provided in continuous rows and aligned with the edge of the laboratory bench to promote good visibility

Equipment Rooms: Equipment rooms lighting systems shall follow a similar approach as the laboratories with the containment barrier at the outlet box and surface mounted light fixtures arranged in a symmetrical pattern.

Imaging Laboratories: Imaging laboratory lighting systems shall also use surface mounted lights with containment at the outlet box. In specific imaging modalities, such as MRI, fixtures shall be made of non-ferrous materials; use DC rated incandescent lamps and use dimming controls. All special requirements shall be coordinated with the manufacturer of each modality. Lights shall be placed in a symmetrical pattern.

## B.8 Lighting Control:

Laboratories shall utilize line voltage toggle switches. Occupancy sensors may be used in lab support and other areas. In addition, specialized lighting controls (such as dimming systems and DC lighting controls) shall be provided per specific program requirements.

## C. BSL3 Laboratory Conductors, Cables, and Boxes:

### C.1 Power Wiring:
Insulation shall be compatible with sealing compound (sealing compound non-deleterious to insulation), using THW, THWN, THHN/THWN, or XHHW, with minimum size #12 wire, except #10 wire for special purpose receptacles.

### C.2 Voice/Data Wiring:
Relevant wiring and sealing requirements for power also apply to voice/data wiring. Cable types shall be determined by NIH IT and manufacturer's recommendations.

### C.3 Fire Alarm Wiring:
Relevant wiring and sealing requirements for power also apply to fire alarm. Cable type(s) shall be provided as required by the system manufacturer.

### C.4 Control Wiring:
Relevant wiring and sealing requirements for power also apply to control wiring. Cable types shall be provided as recommended by the system manufacturer.

### C.5 Security Wiring:
Relevant wiring and sealing requirements for power also apply to security wiring. Cable types shall be provided as recommended by the system manufacturer. The A/E shall coordinate requirements for security wiring, on a per project basis with the Project Officer and Division of Physical Security Management (DPSM).

### C.6 Sealing Requirements for All Systems:
Silicon based caulk shall be provided in all areas. See Chapter 4, Exhibit X4-2-A

### C.7 Boxes for All Systems:
Cast boxes with external mounting provisions, external hub, and gasketed device cover plates shall be provided. All boxes shall be double gang. The box depth shall be at least the next size larger than the minimum code requirement. Wiring shall be surrounded with a 25 mm (1 in.) barrier of silicone caulk within the device box hub. Provide a continuous bead of caulk around the device cover plate and the adjacent surface.

### C.8 Conduit for All Systems:
RGS conduit with threaded fittings shall be used in all BSL3 areas.

## D. ABLS3 Animal Facility Power Requirements:

### D.1 Standby Power Requirements:

In addition to the equipment listed in the BSL3 laboratory standby power requirements the following loads shall be connected to the generator power:

- Animal Watering Systems.
- Animal Caging and Ventilation Systems.

The following load is recommended to be connected to the generator power and shall be determined based on specific program requirements.

- Cage Wash equipment.

## E. ABLS3 Animal Facility Lighting:

### E.1 Lighting Fixtures:

Lighting fixtures for ABSL3 animal research facilities shall meet all requirements for BSL3 research laboratories light fixtures.

### E.2 Lighting Design Criteria by Area:

ABSL3 spaces shall meet all requirements listed under paragraph 10-8 F. Animal Research Facility (Vivarium) Lighting and Controls

# 10-9-20 Design Information

The A/E shall refer to Sections 2-5 and 2-6 in Chapter 2 and the preceding sections of this chapter to make a determination of all applicable provisions that are to be incorporated into the design of the biocontainment facility.

# Telecommunications 11



# Section 11-1: Telecommunications



## 11-1-00 Design Requirements

The following design requirements apply to all telecommunications systems. The goals and objectives are to provide uniformity of design; combine the best overall economy with suitability of design; and be compatible with all other building systems. Provision shall be made for the addition of future requirements as determined by the NIH on a project-by-project basis.

## 11-1-20 Design Information

### A. Reference Design and Safety Guidelines for Telecommunications:

The NIH is a progressive and dynamic biomedical research institution where state-of-the-art medical research is the standard practice. To support state-of-the-art research and medical care, the facilities must also be state-of-the-art. It is the NIH's intent to build and maintain the electrical and communication systems and facilities in accordance with the latest standards.

It has been the NIH experience that the renovation and rehabilitation of existing facilities do not always lend themselves to incorporating the "latest" standards of the industry.

The A/E should be alerted to this situation and make an evaluation early in the de-sign stage to determine the implementation feasibility of the latest standards. The A/E should document such findings, provide recommendations, and report them to the Project Officer for a decision on how to proceed.

The A/E design firm should use and comply with, as a minimum, the latest issue of the following design and safety guidelines. In addition, the A/E should use other safety guidelines received from the NIH Project Officer or as required by the program. The A/E should utilize the latest versions of guidelines available at the time the project proceeds with schematic design.

The reference codes, regulations, and recommended practices include, but are not limited to the latest version of the following:

- American Hospital Association (AHA), Management and Compliance Series, Electrical Systems for Health Care Facilities
- American National Standards Institute (ANSI)
- AHA, Management and Compliance Series, Fire Warning and Safety Systems
- American Society of Mechanical Engineers (ASME) A17.1: Safety Code for Elevators and Escalators
- Electronic Industries Alliance (EIA)
- International Code Council, Inc., International Building Code (IBC),
- International Cable Engineers Association (ICEA)
- International Electro-technical Commission (IEC)
- Institute of Electrical and Electronics Engineers (IEEE), Color Books
- Lightning Protection Institute, LPI 175 Standard of Practice
- National Electrical Code (NEC), National Fire Protection Association (NFPA) Standard 70
- National Electrical Manufacturers Association (NEMA)
- National Electrical Safety Code (NESC) IEEE C2
- NFPA, National Fire Codes (NFC)
- NIH, Design Policy and Guidelines
- NIH, Center for Information Technology (CIT) Guidelines
- Institute of Laboratory Animal Resources (ILAR), The Guide for the Care and Use of Laboratory Animals
- Telecommunications Industries Association (TIA)
- Uniform Federal Accessibility Standards (UFAS)
- Underwriters Laboratories (UL)

## 11-1-30 Design Document Requirements

See Appendix B for detailed requirements of submittals at each phase of the project.

### A. Communications (Schematic, Design Development and Contract Documents)

Communications floor plans, one line diagrams, equipment schedules, miscellaneous details, and cover sheet requirements.

### B. Specifications (Outline and Detail Performance Specifications)

Outline specifications shall be developed at the design development stage and detail performance specifications shall be developed at the contract document stage.

## C. Cost Estimates (Systems and Quantity Takeoff Estimates)

Systems cost estimates shall be developed at design development stage and quantity take-off estimates shall be developed at the contract document stage.

# Section 11-2: Telecommunications/LAN Closet/Room Construction Criteria



## 11-2-00 Design Requirements

These requirements are minimums established by the Center for Information Technology (CIT), Division of Network Systems and Telecommunications (DNST). The telecommunications/LAN closet (referred to as "the closet" in this chapter) houses:

- The transition point between the information technology backbone and the horizontal pathways.
- The horizontal distribution center for the telecommunications/LAN cabling and is where the cable tray and feeder conduits terminate.
- The LAN patch panels, telecommunication cross connect fields, telecommunication and LAN electronic equipment.
- The telecommunications and fiber optic riser cabling and terminations.
- Associated local Uninterruptible Power Supply (UPS) systems.

This space shall not be used for any occupant-related servers and systems. Closets shall be provided in all areas to prevent the use of electrical closets for telecommunication equipment.

### A. Closet Size and Location:

The closet size provided shall be 14 net sq. m (150 sq. ft.) minimum per 930 sq. m (10,000 sq. ft) of occupied space, and with minimum dimensions 3.0 m X 4.5 m. (10 ft. x 15 ft.) There shall be no obstructions in the room, including in the ceiling area/plenum. The closets shall be stacked in multistory buildings.

### B. Quantity:

There shall be a minimum of one centrally located closet per floor. Closet(s) shall be located so the most distant work area outlet does not exceed a 76 m (250 ft.) radius. Additional closets shall be provided as required to maintain the 76 m (250 ft.) radius requirement.

## C. Wall Requirements:

Walls shall extend from the finished floor to the structural ceiling, with a minimum 1-hour fire rated wall. All walls of the closet shall be lined with rigidly installed, wall-to-wall, 20 mm (3/4 in.) A-C grade, 2.440 m (8 ft.) tall fire-retardant plywood. The bottom of plywood shall be 150 mm (6 in.) above finished floor (AFF). All walls and plywood shall be covered with two coats of fire-retardant white paint and with fire rating symbol exposed on each sheet of plywood.

## D. Door Requirements:

The closet shall be provided with a single 915 mm ( 3 ft.) wide x 2,030 mm (80 in) tall door, with standard mortise 1000 series locks. Card access shall be provided. The door shall swing out from the closet and shall be provided with a continuous hinge. A latch-plate guard shall be installed to prevent pry bar entry on double doors or single doors that swing out from closet.

## E. Ceiling Requirements:

Lay-in ceilings are not permitted in the closet. The structural ceiling shall be painted white.

## F. Floor Requirements:

The closet floor shall be off-white, anti static, vinyl composition tile and shall have a minimum load rating of 7.18 kPa (1 psi). All floor penetrations sleeves shall extend 100 mm (4 in) above and below the finished surface

## G. Environmental Requirements:

HVAC systems shall operate 24 hours per day, 365 days per year. If the building's system cannot ensure continuous operation, a stand-alone HVAC unit shall be provided. This unit shall not be placed inside the closet. If an emergency power source is available, the HVAC system that serves the main and/or critical closets shall be connected to that emergency source, as defined by CIT program. The closet shall maintain positive pressure relative to adjacent spaces with a minimum of one air change per hour. The temperature shall be adjust-able from inside the closet. Heat dissipation shall be 4,400 watts per hour, which accommodates for three racks.

## G.1 Environmental Factor Requirements:

The closet shall be designed to maintain a range of temperature between 18°C (65° F) to 24°C (75° F) and relative humidity between 30% and 55% with minimum changes in temperature and humidity. Filtration systems may be required to minimize particle levels in the air. HVAC sensors and controls shall be located in the closet and shall be placed 1.5 m (5 ft.) AFF.

## H. Lighting Requirements:

The closet shall have uniform lighting that provides a minimum of 540 lux (50 FC) when measured 915 mm (3 ft.) AFF. Fixtures shall be a 2-tube, 1.22 m (4 ft.), industrial light fixture with wire guard protection, 32 watt fluorescent T-8 lamps with electronic ballast. Locate light fixtures a minimum of 2.6 m (8.5 ft.) AFF. Coordinate fixture layout with the equipment rack location and the overhead cable trays to ensure the fixtures are not obstructed. At least one fixture in the closet shall be on an emergency lighting circuit.

## I. Utilities/Equipment Requirements:

Utilities and/or equipment not related to the support of the closet such as piping, ductwork, auxiliary cooling unit and distribution of power shall not be located in or traverse the closet. The closet shall not be shared with building or custodial services.

## J. Base Electrical Requirements:

Provide the following in each telecommunications/LAN closet:

- An accessible insulated grounding bus bar.
- A connection of a #2/0 AWG express copper ground wire to the building ground bus bar in the main electrical room and the telecommunications grounding bus bar in each closet. CIT/DNST shall review the final grounding design.
- A #6 AWG grounding jumper from ground bus to all racks inside the closet.
- One double duplex NEMA 5-20R receptacle on emergency power and one double duplex NEMA 5-20R receptacle on normal power with both mounted on the telephone equipment wall field.
- A NEMA 5-20R duplex receptacle on other walls in each closet, located 455 mm (18 in.) AFF.
- One branch circuit panelboard with 42-pole, 3-phase, 4-wire, 225 A with a 100 A main circuit breaker - one for every three stacked closets. The panel shall only feed the closet in which the panel resides and one closet above and one closet below in a stacked room configuration.

## K. Network Equipment Electrical Requirements:

All circuits shall be labeled on each outlet located on the racks. There shall be a minimum of at least two outlets per rack. The bottom of the lowest outlet shall be placed at 610 mm (2 ft.) AFF, the bottom of the upper outlet shall be placed 150 mm (6 in.) above the top of the bottom outlet. Power fed from the bottom of the rack up shall not have conduit bends, only factory conduits shall be accepted. Power feeding the rack shall originate from the closet electrical panel.

The A/E shall contact the CIT Network Infrastructure Section (NIS) at 301-496-4357 to generate a “Request for Reply” for verification of the required type of outlets, determined by manufacturer, equipment size, UPS size and the area to be served. NIS shall make the final determination for power provided to the racks.

## L. Additional Requirements:

A 455 mm (18 in.) wide x 100 mm (4 in.) deep minimum cable tray shall be installed around the main hallway perimeter of the building, and penetrate into and extend the length of the closet. All joints in the tray shall use factory made joint couplings. A #6 AWG copper-bonding jumper shall be installed between each section of the tray and terminated with #2 crimp type connector.

A 305 mm (12 in.) x 25 mm (1 in) ladder rack shall be installed around the closet perimeter and to equipment racks to distribute cable in the closet. There shall be a 305 mm (12 in.) x 25 mm (1 in) ladder rack installed vertically slab to slab behind the metallic sleeves for vertical riser cable support. See Exhibit X11-2-A

A minimum of four 103 mm conduits shall connect the closet with the main closet(s). Each 103 mm (4 in.) conduit bank shall have one conduit installed with three 35 mm (1.5 in.) inner ducts with pull lines.

Provide two-103 mm (4 in.) conduits through roof to nearest telecom closet for antennae connection.

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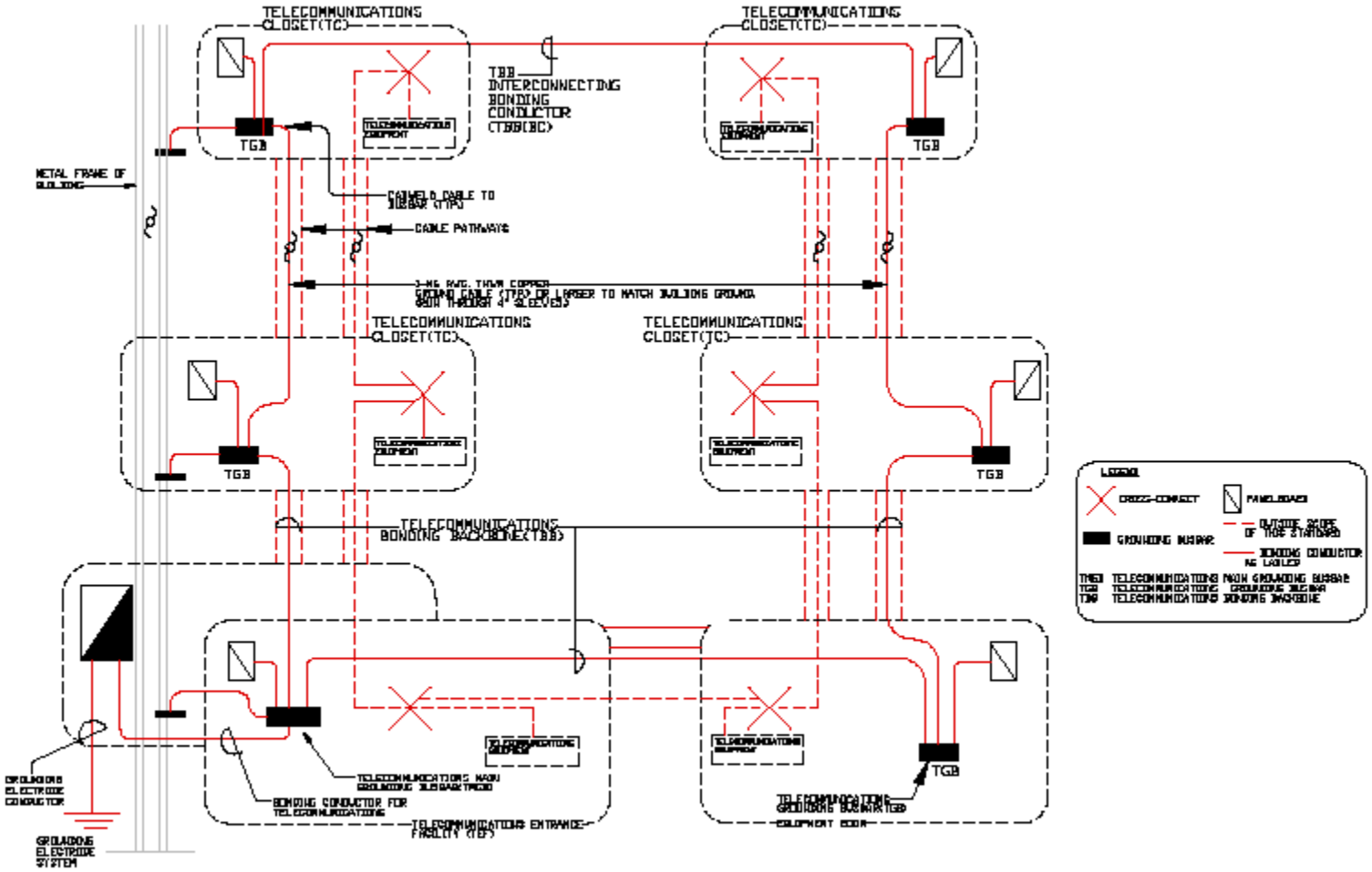


TELECOMMUNICATIONS GROUNDING AND BONDING RISER
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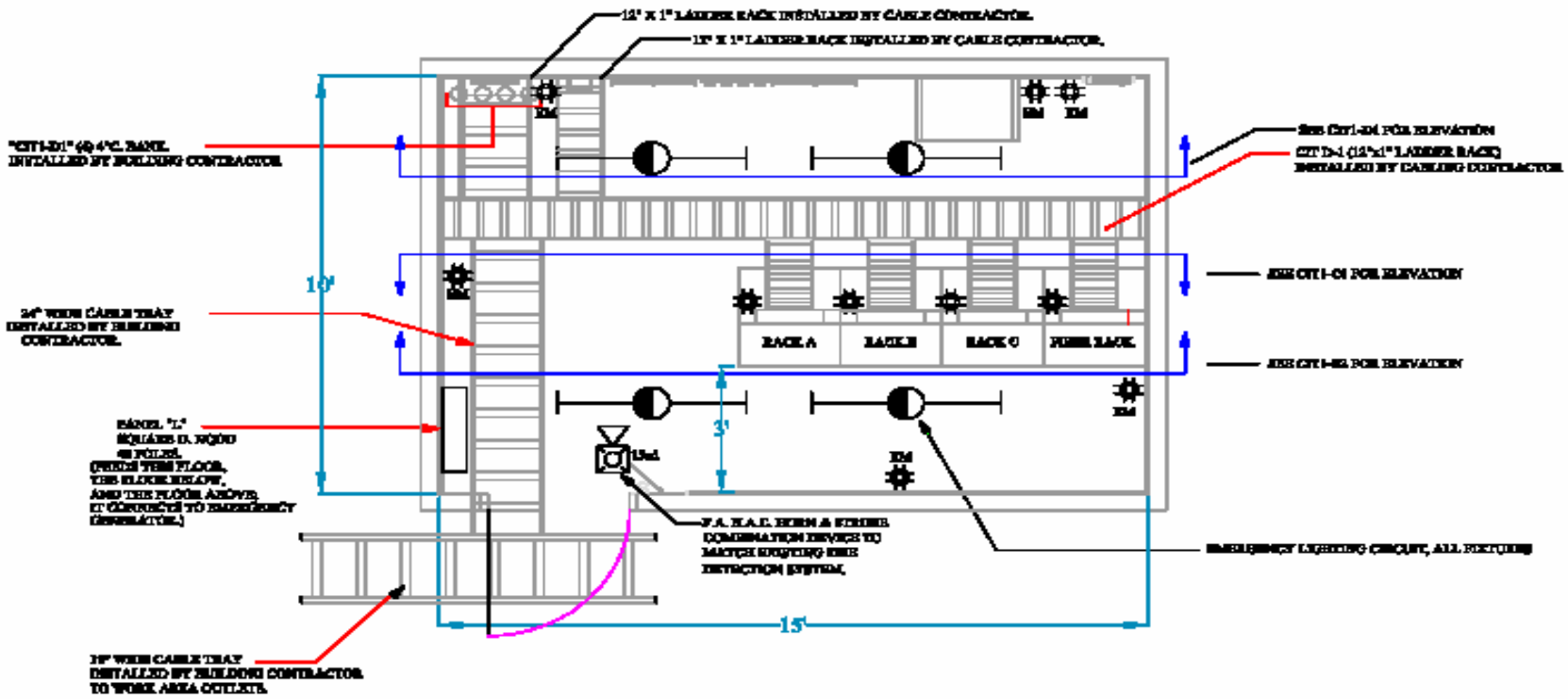


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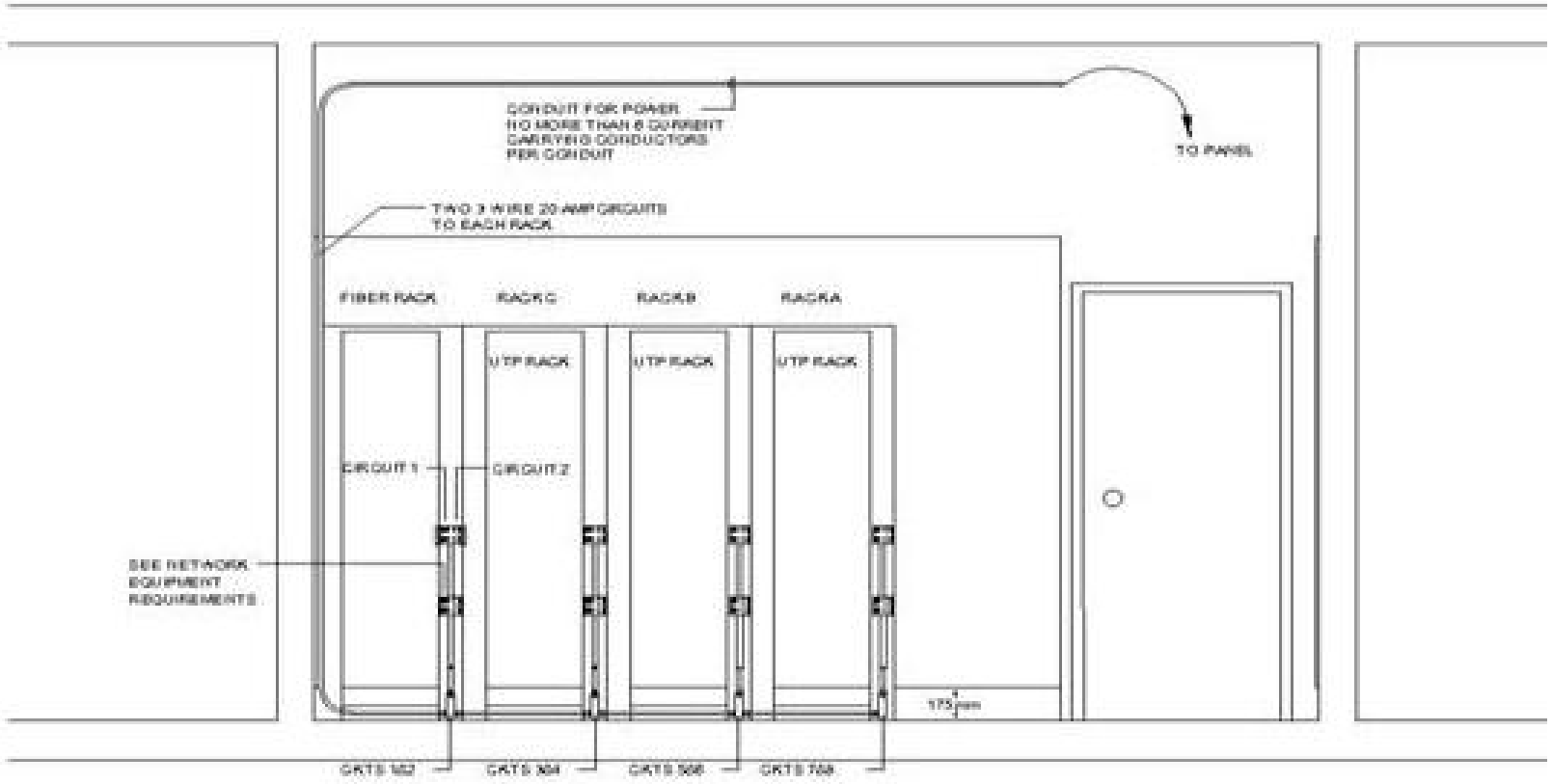


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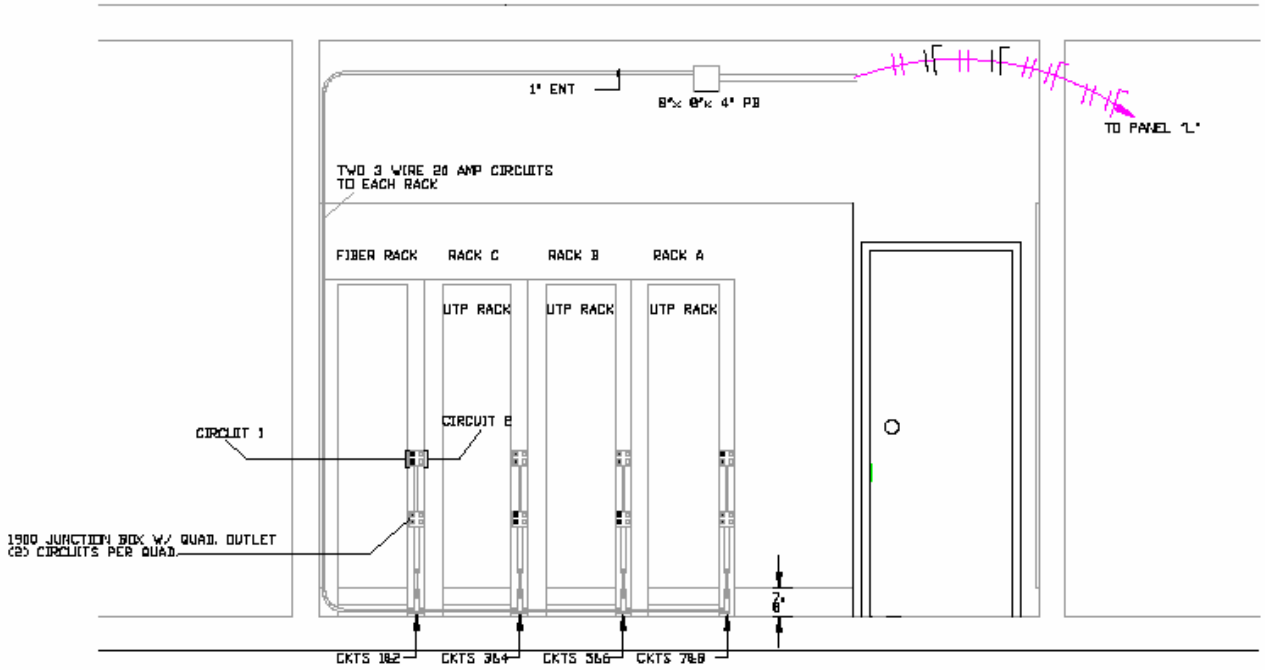


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# Section 11-3: Cable Management



## 11-3-00 Design Requirements

### A. Inter–Building Riser Sleeve/Slot Configuration:

#### A.1. Sleeves or Slots:

Cable sleeves or slots shall be positioned adjacent to the wall on which the backbone cables are to be supported. Sleeves or slots shall not obstruct wall terminating space, that is, they shall not be directly above or below the wall space that is to be used for termination fields. Slots shall be constructed with a minimum 25 mm (1 in.) high curb. Sleeves shall extend a minimum of 25 mm (1 in.) AFF.

Penetrations shall be caulked and sealed as required. See Architectural Chapter 4 Section 4-2-10-B.6 “Joint Sealants and Caulking.” The minimum required quantity shall be applied per code, in addition to specific project needs and/or structural limitations. Provide fire proofing and vermin proofing as required.

#### A.2 Sleeve Quantity and Configuration:

The A/E shall provide sleeve quantity and configuration per ANSI/TIA/EIA-569-B, with the team’s structural engineer’s review and approval of the quantity, location, and configuration of sleeves.

#### A.3 Slot Quantity and Configuration:

The A/E shall provide slot quantity and configuration per ANSI/TIA/EIA-569-B, with the team’s structural engineer’s review and approval of the quantity, location, and configuration of slots.

#### A.4 Open Shafts:

Open cable shafts are used when available and where large quantities of cables are required on a floor that is distant from the main equipment room (ER) (e.g., the main ER is in the basement and a large quantity of circuits are required on the top floor).

## A.5 Large Conduits for Closet Ties and Riser Pathways:

Conduits placed to support risers and closet tie cables shall be of a minimum of 103 mm (4 in.) electrical metallic tubing (EMT). There shall be a pull box every 30.5 m (100 ft.), sized so that exit and reentry of cable is supported in case the pull requires re-rigging and to support the bend radius of the cables to be placed.

## B. Cable Management System Overview (Cable Tray):

Cable management system or cable tray shall be comprised of a continuous rigid welded steel wire mesh cable management system with continuous safety edge wire welded to the top of the tray, and wire mesh welded at all intersections.

The open mesh permits easy access to the tray and provides continuous ventilation of cables installed in the tray. A continuous ground system can be accomplished by the use of approved splices and bonding jumpers.

Non-ferrous or aluminum cable tray shall be used in areas subject to high magnetic fields. Possible restriction may be in place for aluminum cable tray due to radio frequency (RF) interference.

## B.2 Cable Management System Finishes:

Electroplated zinc galvanizing (standard stock finish) is suitable for most indoor applications and shall be used outdoors in mild environments only. Hot dip galvanizing is most suitable for outdoor applications or environments where increased corrosion resistance is desired.

## B.3 Cable Management System Installation:

The cable management system shall be installed using hardware, splice connectors, support components and accessories furnished by the manufacturer. All turns and “waterfalls” shall be of manufactured products. All cutting of the cable management system shall be performed using manufacturer cutting techniques and cutting tools. All cable management systems shall be accessible with a minimum of a 150 mm (6 in.) clearance from top and bottom of the tray. There shall not be a span of a distance of 1,825 mm (6 ft.) or more that does not allow access to the cable tray. The cable tray shall be installed to meet NEC Article 392 and other applicable codes.

Systems other than telecommunications/LAN shall not utilize the LAN cable tray, unless approved by CIT. When approved, other systems may utilize the cable tray system, provided barriers are installed between the systems or J-hooks are provided attached to the cable trays.

## B.4 Cable Management System Sizing (Cable Tray):

Cable management systems sizing shall be no smaller than 100 mm (4 in.) deep x 455 mm (18 in) wide. The final determination of depth, width and layout design shall be coordinated with and approved by CIT.

## C Duct Bank Construction:

All duct bank placed shall be a minimum of a 4-way duct back system in a 2 x 2 configuration. Depending on the size of the building, a larger duct bank may be required. The final sizing of the duct bank system shall be determined by CIT. Duct banks shall be sized at 103 mm (4 in.) rigid plastic conduit; NEMA TC 2, Schedule 40 PVC, rated for use with 90° C conductors under all installation conditions.

Duct banks shall be encased with a minimum of 27 mm (1 in) of concrete over the top ducts. Concrete shall be 20.7-MPa (3000 psi) minimum, 28-day compressive strength with 10-mm (0.4 in.) maximum aggregate. Duct banks shall be placed at a minimum depth of 915 mm (3 ft.) to the top duct and provided with rigid PVC spacers selected to maintain minimum duct spacing and concrete cover depths indicated, while supporting ducts during concreting.

Factory produced “communications” sweeps shall be used in lieu of 90° bends. No more than two 90° bends in any duct bank run.

## D. Fire Stopping:

All fire stopping systems shall meet the UL requirements for the specific type of wall construction and penetration.

## E. Horizontal Pathways:

Work area locations of a CAT5E voice and CAT6 solution shall be sized as a 27 mm (1 in.) EMT conduit to each location. This pathway shall be bonded to the cable management system (cable tray) with a #6 AWG ground. Each conduit shall have a factory produced grommet on the end to facilitate this grounding.

Work area locations of a CAT6 voice and CAT6 solution shall be sized as a 27 mm (1 in.) conduit to each location. This pathway shall be bonded to the cable management system (cable tray) with a #6 AWG ground. Each conduit shall have a factory produced grommet on the end to facilitate this grounding.

Work area locations of a CAT5E voice and CAT7 solution shall be sized as a 35 mm (1.25 in.) EMT conduit to each location. This pathway shall be bonded to the cable management system (cable tray) with a number #6 AWG ground.

Each conduit shall have a factory produced grommet on the end to facilitate this grounding. These conduits shall not have any more than two 90° bends and shall terminate at the closest point. Ground conductor conduit may have up to four 90° bends.

All work area outlets shall have its own conduit pathway; “daisy chaining” of any horizontal pathway is NOT permitted.

If pull boxes are required, they are to be placed every 30.5 m (100 ft.) for placement of tie cables and or larger bundles of unshielded twisted pair (UTP) cable.

# Section 11-4: Site Utility Structures



## 11-4-00 Design Requirements

### A. Outside Plant (OSP) Pull Boxes and Handholes:

#### A.1 Metal Pull Boxes:

Metal pull boxes shall be cast aluminum, sized as indicated, with outside flanges, and recessed, gasketed cover for flush mounting. A nonskid finish shall be provided on the cover, with a cover legend "COMMUNICATIONS."

#### A.2 Non-Metallic Pull Boxes:

Non-metallic pull boxes shall be of a molded high density polyethylene. The flange around the base shall prevent frost damage from heaving or tilting. Non-metallic pull boxes shall be placed at a depth of 915 mm (3 ft.) to the top of box. The cover shall be of high density polyethylene with a cover legend "COMMUNICATIONS."

### B. Underground, Pre-cast Concrete Utility Structures (Manholes):

Manholes shall be pre-cast units comprised of interlocking, mating sections, complete with accessory items, hardware, and features as indicated. Manholes shall include concrete knockout panels for conduit entrance and sleeve for ground rod. The structure shall be designed per ASTM C 858. The structural design loading shall be per ASTM C 857, Class A-16 and the fabrication shall be per ASTM C 858.

The cover shall be recessed to accept finish materials in landscaped and paved areas. Joint sealant shall be a continuous extrusion of asphaltic-butyl material with adhesion, cohesion, flexibility, and durability properties necessary to withstand maximum hydrostatic pressures at the installation location with the ground water level at grade. Project specifications shall include quality control for inspecting structures per ASTM C 1037.

## B.1 Accessories:

Accessories indicated shall conform to the following:

- Frames and Covers: Cast iron with cast-in legend "COMMUNICATIONS". Machine cover-to-frame bearing surfaces.
- Sump Frame and Grate: Comply with FS RR-F-621, Type VII for frame and Type I for cover.
- Pulling Eyes in Walls: Eyebolt with reinforcing-bar fastening insert; 50 mm (2 in.) diameter eye; and 25 mm x 100 mm (1 in. x 4 in.) bolt. Working load embedded in 150 mm (6 in.), 27.6-Mpa (4000 psi) concrete, and 58 kN (13000 lbf) minimum tension.
- Pulling and Lifting Irons in Floor: 26 mm (1 in.) diameter, hot-dip galvanized, bent steel rod, stress relieved after forming, and fastened to reinforced rod. Exposed triangular opening. Ultimate yield strength shall be 180 kN (40,000 lbf) shear and 270 kN (60,000 lbf) tension.
- Bolting Inserts for Cable Stanchions: Flared, threaded inserts of non-corrosive, chemical-resistant, nonconductive thermoplastic material; 13 mm (0.5 in.) ID x 69 mm (2.75 in.) deep, flared to 32 mm (1.25 in.) minimum at base. Tested ultimate pullout strength shall be 53kN (12,000 lbf) minimum.
- Expansion Anchors for Installation after Concrete Is Cast: Zinc-plated, carbon-steel-wedge type with stainless-steel expander clip 13 mm (0.5 in.) bolt size, 24 kN (5300 lbf) rated pullout strength, and minimum 30 kN (6800 lbf) rated shear strength.
- Cable Stanchions: Hot-rolled, hot-dip galvanized, T-section steel, 57 mm (2.25 in) size, punched with 14 holes on 38 mm (1.5 in.) centers for cable-arm attachment.
- Cable Arms: 5 mm (0.2 in.) thick, hot-rolled, hot-dip galvanized, steel sheet pressed to channel shape; 300 mm (12 in.) wide by 350 mm (14 in.) long and arranged for secure mounting in horizontal position at any position on cable stanchions.
- Cable-Support Insulators: High-glaze, wet-process porcelain arranged for mounting on cable arms.
- Ground Rods: Solid-copper-clad steel, 21 mm (0.75 in.) diameter x 3.05 m (10 ft.) length.
- Ground Wire: Stranded bare copper, #6 AWG minimum.
- Duct Sealing Compound: Non-hardening; safe for human skin contact; not deleterious to cable insulation; workable at temperatures as low as 1°C (34 °F); and capable of withstanding temperature of 149°C (300 °F) without slump and of adhering to clean surfaces of plastic ducts, metallic conduits, conduit coatings, concrete, masonry, lead, cable sheaths, cable jackets, insulation materials, and common metals.

## B.2 Construction Materials:

The A/E shall design damp-proofing to comply with applicable codes and standards. Concrete brick shall be specified as ASTM C 55, Type I, Grade N; and mortar shall be specified as ASTM C 270, Type M, except for quantities less than 60 L (2 cu. ft), where packaged mix complying with ASTM C 387, Type M may be used. Concrete strength shall be specified as 20.7 MPa (3000 psi) minimum, 28-day compressive strength, with a maximum 10 mm (0.4 in.) aggregate.

# Section 11-5: Audio Visual (AV) Requirements



## 11-5-00 Design Requirements

### A. Audio Visual (AV) Requirement:

All AV requirements shall be coordinated with the equipment supplier.

### A.1 Conduit:

All AV conduits to floor boxes shall be direct pulls (home runs) from the rack location. No AV cabling shall be pulled through CIT data cabling pathways, including cable tray. All floor box cabling shall be pulled through 53 mm (2 in.) rigid conduit, unless otherwise noted. All single-gang endpoint cabling shall be pulled through 27 mm (1 in.) rigid conduit, unless otherwise noted. All double-gang endpoint cabling shall be pulled though 35 mm (1.25 in.) rigid, unless otherwise noted.

### A.2 Floor Boxes and Wall Plates:

All AV cabling to the floor shall be pulled through floor boxes. AV floor boxes shall measure a minimum depth of 100 mm (4 in.) and shall feature separate compartments for data, power and AV. Receptacle heights shall be determined in the field, unless otherwise noted. Double-gang wallplates shall be specified for all connectivity points, unless otherwise noted. Poke-throughs are only acceptable as retrofit last resort. Poke-throughs, if used, shall be open pass-throughs and feature no connectors, cabling, or power other than that necessary for AV connectivity.

### A.3 Cabling:

Plenum cabling shall be used in all circumstances where cabling does not pass directly through conduit for the length of the run, red-green-blue-horizontal-vertical (RGBHV) and balun cabling shall have sufficient bandwidth to support 1,080p signals for a distance of 45.75 m (150 ft.). S-video and RGBVH connectivity shall be provided via powered balun as feasible. Audio cabling shall be 2C:22 shielded. Composite cabling shall be RG-6. RGBVH cabling shall be RG-174. Balun and data cabling shall be CAT5e or CAT6.

## A.4 Closets:

AV cabling shall terminate in an AV equipment rack in the nearest telephone closet, intermediate distribution frame (IDF) or main distribution frame (MDF) unless otherwise determined by the collaborative technology innovation and video services group (NIH/CT/OD/CTIVS) engineering staff. Local use items such as user interface devices shall be located in a small professional AV rack, podium, or millwork in the room as determined by the NIH/CT/OD/CTIVS engineering staff. Each rack shall have a dedicated 20-A circuit. Two NEMA L5-20R receptacles shall be provided per rack.

## A.5 Display Devices:

Flat screens displays shall be either LCD or plasma. The standard plasma screen shall be 1.27 m (50 in.) diagonally. The standard LCD screen size shall be 1.17 m (46 in.) diagonally. Flat screen displays shall be professionally connected for AV usage, with the following installation requirements: DVI connectivity, VGA and/or RGBHV connectivity, component connectivity, S-video connectivity, and composite connectivity. Audio reproduction for isolated wall mounted flat screen systems shall be provided by attached speakers.

Projection systems shall be ceiling mounted or portable. Projectors shall be rated 3,000 lumens full white at a minimum. Video to any display device shall be scaled to the highest possible resolution whenever possible. The native resolution of a flat screen display device shall be WXGA or better. The native resolution of a projector shall be XGA or better. Projector mounting hardware supported to slab shall be provided at location(s) to be determined. Mounting hardware shall feature threaded rod or channel in a 610 mm x 610 mm (24 in. x 24 in.) matrix mounted between 305 mm (12 in.) and 610 mm (24 in.) above grid; and shall be sufficient to support 39 kg (85 lb.) dead weight, unless otherwise noted. Flat screen mounting backing, in the form of cross-braced plywood attached to stud, shall be provided at a location to be determined. Backing shall be sufficient to support 182 kg (400 lb) dead weight on a 610 mm (24 in.) moment, unless otherwise noted.

## A.6 External Devices:

Projection screen mounting hardware supported to slab shall be provided at location(s) to be determined. Mounting hardware shall feature threaded rod or channel mounted between 305 mm (12 in.) and 610 mm (24 in.) above grid and shall be sufficient to support 182 kg (400 lb) dead weight, unless otherwise noted.

All ceiling speakers shall be individually supported to the slab or other ceiling support. If the ceiling is too high for contractor access, post grid, tie points or cross braces shall be provided between 305 mm (12 in.) and 610 mm (24 in.) above grid. Ceiling speakers shall be

supported using 18 AWG steel wire. Speaker systems shall be 70V unless otherwise noted. Cameras shall be S-video capable. Ceiling microphones shall not be used.

## B.7 General Notes:

NIH/CT/OD/CTIVS is not responsible for carpentry, millwork, electrical work, or painting. NIH/CT/OD/CTIVS is not responsible for replacing or cutting grid-work around ceiling-mounted devices, including electric screens. Replacement acoustic tiles shall be provided for any installation featuring ceiling mounted devices.

# Section 11-6: Antenna, Communications Devices & Miscellaneous Requirements



## 11-6-00 Design Requirements

### A. Distributed Antenna System Requirements:

The distributed antenna system is a broadband, in-building, antenna system designed for the transmission of multiple radio frequency (RF) signals simultaneously over a passive antenna infrastructure. This system shall be compatible with the existing distributed antenna system. See Exhibit X11-6-A "In-Building Signal Amplification System (BDA) Regulations."

The basic distributed antenna system shall accommodate a broad range of wireless services operating between 400 MHz to 2,400 MHz (such as two-way radio, first responder, paging, cellular & PCS, WiFi and others) and shall be expandable to accommodate additional wireless services in both the 150 MHz (VHF) and 5800 MHz (802.11a) frequency bands.

The distributed antenna system provider shall provide the RF expertise, engineering & operations teams that can configure the distributed antenna system to provide fully engineered, comprehensive coverage throughout the facility and overall wireless systems capacity to meet even the most demanding services and applications needs.

The distributed antenna system shall deliver wireless accessibility everywhere in the building, shall be accessible by multiple users, using multiple technologies & applications, and shall have a predictable level of reliability equivalent to other building "utilities" such as electricity and air conditioning.

### A.1 System Architecture:

The distributed antenna system shall provide a single point of connection for all of the wide area services providers' equipment such as two-way radio, first responder, paging, cellular/PCS, 3G, etc. The system's portal shall combine all of the different signal inputs onto a single riser cable, which is distributed vertically throughout the building. At each segment this signal energy shall combine with the RF signal outputs from the local area services

equipment located on each floor (such as WLAN, location services, enterprise voice, monitoring, building automation, security, etc) and is transmitted in a combined fashion throughout the segment over a highly engineered network of RF distribution cables and broadband antennas.

All of the individual components that make up the distributed antenna system (including the portal, vertical riser cables, horizontal distribution cables, and broad-band antennas) are passive in nature; require no electrical power, software or ongoing management or monitoring; and are designed for many years of reliable and unattended operation.

## A.2 System Extended Architecture:

For individual buildings (or multi-building campuses) that exceed the capacity of a single distributed antenna system zone, the distributed antenna system can be expanded with third party RF optical repeater equipment.

The extended architecture involves connection of the wireless portal from the first distributed antenna system zone directly onto the wide area service providers' carrier equipment. RF optical repeaters are then used to extend each carrier's RF signal out to each of the adjacent buildings where it is connected onto the wireless portal serving that zone. In this manner, a single distributed antenna system zone can be extended to create a system of virtually any size and capacity.

## A.3 Wireless LAN (WLAN) Architecture:

The distributed antenna system shall provide the WLAN architecture with the dual concepts of "layered" capacity and deterministic RF coverage.

Layered capacity means the combining of the RF signals from multiple 802.11 access points (AP's) (up to three 802.11b/g AP's, or in multiples of three 802.11a AP's) over a single coverage area. This is achieved by passively isolating, filtering & combining the AP output signals onto a single RF stream.

## A.4 System Configurations:

The following products and services shall be provided as follows: project scope, site survey, wide area services design, wireless portals, WLAN design, customer design documentation, antennas, installation, project management, integration of wireless services, testing & acceptance.

## A.5 Third Party Equipment – Interface Requirements:

The distributed antenna system shall be designed based on open architecture concepts and is implemented entirely within the bounds of an open system interconnection (OSI) Layer 1 definition. This allows for the connection of multiple systems and devices without the need for proprietary interfaces or consideration of any specific Layer 2 or Layer 3 signaling limitations.

The distributed antenna system shall be part of a compatibility partner program in order to provide NIH with the means to verify inter-operability between the distributed antenna system and any third party systems, devices and applications. This program shall ensure the allocation of resources required to address all of NIH network interface needs and priorities. The distributed antenna system shall have a compatibility laboratory where the distributed antenna system engineers test and evaluate directly with the product vendor any devices or technologies that a customer may want to deploy over the distributed antenna system.

## A.6 Wide Area Services Equipment (Cellular/PCS, Two-way, First Responder, and Paging):

The distributed antenna system coverage designs shall be based on the assumption that each wide area services (WAS) provider shall provide:

- RF connectivity at each connection port on every wireless portal, at a signal level of +28 dbm per RF channel.
- Sufficient RF filtering on each of their RF connections in order to prevent interference with other RF signals of other WAS providers that may be operating on the inner wireless system in adjacent frequency bands.

In the event that any WAS provider is unable to provide sufficient amplification or filtering equipment in order to meet the distributed antenna system design requirements, further amplification or filtering equipment may be necessary prior to connection of that WAS providers' signal onto the distributed antenna system.

The distributed antenna system shall be able to provide the additional amplification and filtering equipment required for each WAS provider's connection, such as RF optical converter equipment, off-air bidirectional repeater equipment, or passive band-specific filter devices.

## A.7 Access Point Equipment:

The distributed antenna system shall be compatible with 802.11a/b/g access points on the market today. Specific compatibility testing is available to verify antenna port configura-

tions, output signal levels, and to complete the detailed design of the distributed antenna system, as required.

Unless otherwise noted, the distributed antenna system WLAN architecture shall be designed based upon access points having easily accessible external antenna ports and the following minimum 802.11 RF signal levels:

- +17 dbm per 802.11a channel.
- +20 dbm per 802.11b channel.
- +15 dbm per 802.11g channel.

In the event that the specific model of 802.11 access point selected by NIH can not provide either external antenna port access or the minimum signal strengths mentioned above, the distributed antenna system design shall be modified to accomplish the NIH requirements.

### A.8 Enabled Devices and Software Applications:

The distributed antenna system has been deployed successfully with many different combinations of 802.11 enabled devices and software.

As different manufacturers' devices and software applications have varying design needs, it is critical to the successful design and implementation of the distributed antenna system that the contracted distributed antenna system shall be advised of all 802.11 enabled devices and software applications planned for deployment on the system, as NIH needs dictate.

In the event that the specific combination of devices or applications planned for deployment is new to the contracted distributed antenna system, the contracted distributed antenna system provided shall make available its compatibility partner program in order to verify interoperability prior to connection onto the distributed antenna system.

## B. Communication Devices

### B.1 Blue Light Phones:

A "blue light phone" is placed to serve the NIH community with a communications device in time of emergency. It also has the capability to be used as a "campus only" telephone for basic contact and for information. There are two types of "blue light phones" placed at the NIH:

- Wall mounted units: These units require a conduit back to a central telecommunications closet or a communications management system, as well as a 120VAC circuit: 32 watts load. Wall mounted units are generally installed by a CIT contractor.
- Pedestal mounted units: These units average in height between 1,550 mm (5 ft.) and 2,895 mm (9.5 ft.). Pedestal mounted phones require a conduit and access to a 120 V AC circuit: 32 watts maximum load connection, but are usually placed by the general contractor as they require concrete placement and mounting bolts for installation. Cabling for the telecommunication connection is provided by the CIT cabling contractor.

### B.2 BAS, Utility Monitoring and Security Systems:

BAS, utility monitoring, and security systems vary widely in requirements for connections used to monitor their systems however, the following shall always apply:

- Provide an EMT conduit pathway(s) back to a closet or closest cable management system.
- The pathway shall never exceed 90 m (295 ft.) in length when utilizing LAN communications.

CIT shall provide the cabling via an NIH cabling contractor to support these requirements and shall assist on determining cable types required to support the installation.

CIT NIS shall participate in this design process to ensure that the connections required can be supported. Refer to Section 11-2.K “Network Equipment Electrical Requirements” for contact information.

## C. Miscellaneous

### C.1 Elevator Room Support:

Elevator rooms shall be provided with an EMT conduit pathway(s) back to a closet or closest cable management system, not to exceed 90 m (295 ft.) in length. Elevator rooms require a pathway to support a wall phone located at 1.22 m (4 ft.) AFF and a pathway to support each controller.

### C.2 Renovation Work:

All abandoned cabling in renovated areas shall be removed and recycled in accordance with NIH CIT’s recycling requirements. CIT shall be responsible for disconnecting and labeling all cables to be removed.

## C.3 Cable TV System:

Some building on campus are wired for cable TV. Cable outlets shall adhere to the requirement of Section 11-3-00-E Horizontal Pathways for cabling to be provided by the local cable TV company.

# In-Building Signal Amplification System (BDA) Regulations

Department of Permitting Services
Division of Building Construction
255 Rockville Pike, 2nd Floor, Rockville, Maryland 20850

## Montgomery County In-Building Signal Amplification System Standard

Effective April 1, 2005, Montgomery County adopted regulations to require in-building signal amplification systems in certain buildings. The regulation was in form of an amendment to the 2003 International Building Code and is as follows:

## SECTION 3110 IN-BUILDING SIGNAL AMPLIFICATION SYSTEM

**Section 3110.1 General.** The provisions of this Section shall apply to all newly constructed below ground floors of a building, all floors in buildings greater than 25000 $ft^2$ per floor, and to all floors of buildings greater than 3 stories in height of Type I and II constructions.

**Exception:** The requirements of this section shall not apply to areas within an individual dwelling unit.

**Section 3110.2 Where Required.** Every floor area in a building or structures which can not achieve the **required level of radio coverage as established by Montgomery County Department of Technology Services (DTS)** shall be provided with in-building signal amplification system.

**Section 3110.3 Inspection and Testing.** Radio coverage and in-building signal amplification systems must be tested, and inspected by approved individuals. The results of the testing and inspection shall be certified to the code official prior to issuance of an occupancy permit

## REQUIRED LEVEL OF SIGNAL COVERAGE AS ESTABLISHED BY DTS

- Signal measurement is required to be -95dbm or above at a given point;
- Entire building is 95% or above covered (including all underground levels, basement, elevators, stair-ways, etc) at 95% of the time;
- In-building signal amplification system is required to provide coverage at Delivered Audio Quality (DAQ) 3.4 level or above. DAQ 3.4 is defined as “speech understandable without repetition. Some noise/distortion present.”
- Measurements shall be performed using the Montgomery County Frequency Chart.

**Additional Information:**

Prior to issuance of an occupancy certificate, a registered design professional must certify that the building achieves the required level of radio coverage as established by DTS. This certificate must be presented to the building official upon request and must be presented in the form established herein.

Please note it is building owner’s responsibility to hire a professional consultant to evaluate and test the required level of coverage in the building and to design and install (if required) the in-building signal amplification system.

**Questions:**

For questions regarding in-building signal amplification system standard or signal coverage you may contact Department of Technology Services via phone at 240-777-5203 or by email at BDAStandardQuestions@montgomerycountymd.gov.

## Montgomery County Frequency Chart

| CHANNEL No. | Base Rx | Base Tx | CHANNEL TYPE |
|---|---|---|---|
| 1 | 823.9375MHz | 868.9375MHz | CONTROL CHANNEL |
| 2 | 823.8875MHz | 868.8875MHz | CONTROL CHANNEL |
| 3 | 823.8625MHz | 868.8625MHz | CONTROL CHANNEL |
| 4 | 823.6875MHz | 868.6875MHz | CONTROL CHANNEL |
| 5 | 823.6375MHz | 868.6375MHz | VOICE |
| 6 | 823.6125MHz | 868.6125MHz | VOICE |
| 7 | 823.4375MHz | 868.4375MHz | VOICE |
| 8 | 823.3875MHz | 868.3875MHz | VOICE |
| 9 | 823.3625MHz | 868.3625MHz | VOICE |
| 10 | 823.2750MHz | 868.2750MHz | VOICE |
| 11 | 823.1625MHz | 868.1625MHz | VOICE |
| 12 | 823.1125MHz | 868.1125MHz | VOICE |
| 13 | 822.9125MHz | 867.9125MHz | VOICE |
| 14 | 822.8875MHz | 867.8875MHz | VOICE |
| 15 | 822.8375MHz | 867.8375MHz | VOICE |
| 16 | 821.6500MHz | 866.6500MHz | VOICE |
| 17 | 821.4875MHz | 866.4875MHz | VOICE |
| 18 | 821.3375MHz | 866.3375MHz | VOICE |
| 19 | 821.2750MHz | 866.2750MHz | VOICE |
| 20 | 821.2125MHz | 866.2125MHz | VOICE |

# CERTIFICATE OF RADIO COVERAGE COMPLIANCE

Project Name: _____

Project Address: _____

Building Permit Number: (A/P): _____

Design Professional Engineer of Record: _____

I have tested the building for radio coverage level(s) in accordance with the Montgomery County Department of Technology Services (DTS) standard. To the best of my information, knowledge and belief, the radio coverage levels for this project is in accordance with the specifications and is in compliance with DTS standards and regulations.

Respectfully submitted,

_____

Signature of Design Professional Engineer of Record Date

_____

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# High Containment Research Facilities

12

# Security Sensitive

**Division of Technical Resources**

**Office of Research Facilities**

**The National Institutes of Health**

# Appendix A

**References, Design and Safety Guidelines, Health and Safety Regulations, Codes, and Standards**

A.1 **General Health and Safety:** The latest edition/revision of all references cited (Regulations, Executive Orders, Standards, Manual Issuances, and Guidelines) shall be used.

| Part 1910 - General Industry Standards | |
|---|---|
| Subpart D | Walking - Working Surfaces (1910.21-.30): placement and structure of platforms, catwalks, etc. |
| Subpart E | Means of Egress (1910.35-.38): employee's emergency escape requirements |
| Subpart G | Occupational Health and Environmental Control (1910.94-.100): ventilation, noise control, ionizing/nonionizing radiation |
| Subpart H | Hazardous Materials (1910.101-.126): storage, handling of hazardous materials |
| Subpart J | General Environmental Controls (1910.141-.147) safety color coding and lock-out/tag-out systems |
| Subpart L | Fire Protection (1910.155-.165): sprinkler, detection, and alarm systems |
| Subpart N | Materials Handling and Storage (1910.176-.184): cranes, conveyance systems |
| Subpart O | Machinery and Machine Guarding (1910.211-.219): mechanical equipment (hard wired and/or designed in) and power-transmission apparatus |
| Subpart S | Electrical (1910.301-.399): design safety standards, hazardous locations, special- purpose systems, and safety-related maintenance requirements (design in) |
| Subpart Z | Toxic and Hazardous Substances (1910.1000-.1450): protection from airborne hazardous substances; provides specific guidance to toxic chemicals, e.g., ethylene oxide (see 1910.1047) |

A.2 Federal Regulations and Executive Orders: Occupational Safety and Health Administration (OSHA), Title 29 of the Code of Federal Regulations (29 CFR)

| Part 1926 - Construction Industry Standards | |
|---|---|
| Subpart C | General Safety and Health Provisions (1926.20-.35): fire protection, illumination, and sanitation during construction |
| Subpart D | Occupational Health and Environmental Controls (1926.50-.66): protect workers, public from noise, radiation, gases/vapors, asbestos, lead, and emergency response |
| Subpart E | Personal Protective and Life Saving Equipment (1926.95-.107): PPE, lifelines, and safety nets |
| Subpart F | Fire Protection and Prevention (1926.150-.159): materials protection against ignition sources, extinguishers |
| Subpart G | Signs, Signals and Barricades (1926.200-.203): warning signs, signals, and barriers around construction |
| Subpart H | Materials Handling Storage, Use and Disposal (1926.250-.252): movement of materials; disposal of construction debris |
| Subpart J | Welding and Cutting (1926.350-.354): fire protection and exposure protection |
| Subpart K | Electrical (1926.400-.449): electrical systems in construction related to worker/public protection |
| Subpart L | Scaffolding (1926.450-.454): requirements of design and use |
| Subpart M | Floor and Wall Openings (1926.500-.503): use of guardrails, handrails, etc. |
| Subpart N | Cranes, Derricks, Hoists, Elevators and Conveyors (1926.550-.556): materials movement systems use |
| Subpart O | Motor Vehicles, Mechanized Equipment & Marine Operations (1926.600-606): construction vehicles, material-handling equip. |
| Subpart P | Excavations (1926.650-.652): trenching and shoring requirements |
| Subpart Q | Concrete and Masonry Construction (1926.700-.706): requirements related to construction with these building materials |
| Subpart R | Steel Erection (1926.750-.753): assembly requirements |
| Subpart T | Demolition (1926.850-.860): removal, storage, and disposal of building materials |
| Subpart V | Power Transmission and Distribution (1926.950-.960): grounding, overhead/underground lines |
| Subpart X | Stairways and Ladders (1926.1050-.1060): setup, construction, and use requirements for temporary activities |
| Subpart Z | Toxic and Hazardous Substances (1926.1100-.1152): protection against exposures from use of chemicals |
| Part 1960 - Federal Employee Safety and Health Programs (Latest Edition) | |
| Subparts A-K | Requirements to establish and maintain Federal Agency OSH programs |
| Executive Order | |
| Executive Order 12196 | Occupational Safety and Health Programs for Federal Employees, effective July 1980 |

## A.3 State Regulations

- Maryland Occupational Safety and Health Administration: Code of Maryland Regulations (COMAR), Title 9, Subtitle 12, Chapter 20, Occupational Safety and Health.
- Refer to local and State occupational safety and health administration guidelines.

## A.4 Other Federal Agency Regulations and Policies

| | |
|---|---|
| **General Services Administration** | |
| 41 CFR, Management of Federal Facilities | |
| **Department of Transportation** | |
| 49 CFR Parts 171-179, Hazardous Materials Handling and Transport Requirements | |
| **Department of Health and Human Services (DHHS)** | |
| *Safety Management Manual* | |
| *Environmental Management Manual* | |
| **National Institutes of Health** | |
| NIH Manual Issuance 3032, *Solid Waste Management* | |
| NIH Manual 1342, *Occupant Evacuation Plan* | |
| NIH Manual Transmittal 1361, *Corridor Utilization Policy* | |
| NIH Division of Engineering Services (DES), *Instruction Manual* | |
| Code 1340-2 | Safety Precautions and Procedures Related to Low Voltage Electrical Circuits |
| Code 1340-5 | Safety Precautions and Procedures Relating to Radiation Hazards |
| Code 1340-6 | Policy and Procedures for Working with Asbestos |
| Code 1340-7 | Procedures for Entering Manholes or Other Below Grade Confined Spaces |
| Code 1340-11 | DES Procedures for Handling PCBs |
| Code 1340-12 | Walking and Working Surfaces |
| NIH Specification Section | "Use, Handling, Storage, Transporting, Accumulation and Disposal of NIH Controlled Material" |

| | |
|---|---|
| NIH Specification Section | "Safety and Health" |
| NIH Specification Section | "Removal of Asbestos Materials" |
| NIH Specification Section | "Fume Hood, Laboratory, Air By-Pass Type" |

## A.5 Industry Consensus Standards

| |
|---|
| National Institute of Occupational Safety and Health (NIOSH), Cincinnati, OH |
| *Guide to Chemical Hazards Handbook* |
| American Conference of Governmental Industrial Hygienists (ACGIH), Lansing, MI |
| *Industrial Ventilation: A Manual of Recommended Practice* |
| *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices* |
| American National Standards Institute (ANSI), New York |
| *Fundamentals Governing the Design and Operation of Local Exhaust Systems* |
| Numerous committee papers on materials and systems certifications (see attached cross-reference listing in OSHA publication of OSHA regulatory criteria and their requisite ANSI standards) |
| American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), New York |
| Standard 62, *Ventilation for Acceptable Indoor Air Quality* |
| Standard 55, *Thermal Environmental Conditions for Human Occupancy* |
| *ASHRAE Handbook - HVAC Applications* |
| American Society of Testing Materials (ASTM), West Consbohocken, PA |
| Annual books of ASTM standards, verifying minimum quality standards for various construction materials and products |
| National Sanitation Foundation |
| *NSF 49-1992, Class II (Laminary Flow) Biohazard Cabinetry* |
| Building Officials and Code Administrators International, Inc. (BOCA), Country Club Hills, IL |
| *International Mechanical Code* |

| General Reference Publications |
|---|
| *Patty's Industrial Hygiene and Toxicology,* Volume I, Wiley-Interscience, New York |
| *The Industrial Environment: Its Evaluation and Control,* GPO, DHHS, NIOSH, Washington, DC |

## A6 Biosafety Regulations

The latest edition/revision of all references cited (Regulations, Executive Orders, Standards, Manual Issuances, and Guidelines) shall be used.

### A.6.a Federal Regulations

- U.S. Department of Labor, OSHA, Occupational Exposure to Bloodborne Pathogens, 29 CFR 1910.1030
- U.S. Department of Labor, OSHA, Enforcement Policy and Procedures for Occupational Exposure to Tuberculosis
- U.S. Department of Labor, OSHA, Specifications for Accident Prevention Signs and Tags, 29 CFR 1910.145

### A.6.b State Regulations

- State of Maryland, Department of Environment (MDE), Title 26, Subtitle 13: Disposal of Controlled Hazardous Substances, Chapter 11, Special Medical Wastes
- Refer to local requirements for the disposal of controlled hazardous substances and/or medical pathological waste.

### A.6.c Industry Standards

| American Conference of Governmental Industrial Hygienists |
|---|
| *Industrial Ventilation: A Manual of Recommended Practices*, Cincinnati, OH |
| **National Sanitation Foundation** |
| *NSF 49-1992, Class II (Laminar Flow) Biohazard Cabinetry* |
| **American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)** |
| Chapter 7, Health Care Facilities, in *Applications Handbook*, Atlanta, GA |
| Chapter 16, Air Flow Around Buildings: in *Fundamentals Handbook*, Atlanta, GA |
| |

| U.S. Department of Health and Human Services (DHHS), Public Health Service, CDC/NIH |
|---|
| *Biosafety in Microbiological and Biomedical Laboratories*, DHHS Pub. No. (CDC) 93-8395 |
| *Guide for the Care and Use of Laboratory Animals*, DHHS Publication No. (NIH) 85-23 |
| DHHS, NIH*: Chemical Hygiene Plan* |
| DHHS, NIH, *Guidelines for Research Involving Recombinant DNA Molecules*, 66 FR 1146 |
| *Proceedings of the National Cancer Institute Symposium on Design of Biomedical Research Facilities*, Cancer Research Safety Monograph Series, Volume 5, NIH Pub. No. 81-2305 |
| DHHS, PHS, CDC/NIH: *"Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets," 2nd (Sept 2002) or later edition.* |

## A.7 Radiation Safety Regulations

The latest edition/revision of all references cited (Regulations, Executive Orders, Standards, Manual Issuances, and Guidelines) shall be used.

### A.7.a Federal Regulations, Executive Orders, and Regulatory Compliance Requirements

| Environmental Protection Agency (EPA) |
|---|
| Presidential Documents, Federal Register, Volume 52, No. 15, Tuesday, January 27, 1987, "Radiation Protection Guidance to Federal Agencies for Occupational Exposure; Approval of nental Protection Agency Recommendations" |
| EPA Standards for Airborne Emission of Radionuclides, 40 CFR Part 61-National Emission Standards for Hazardous Air Pollutants, 40 CFR Part61 |
| EPA, National Emission Standards for Hazardous Air Pollutants (NESHAPs), 40 CFR, Part 61, Subpart I |
| **Occupational Safety and Health Administration (OSHA)** |
| Ionizing Radiation, Section 1910.96 |
| Memorandum of Understanding Between OSHA and the NRC, dated December 23, 1989 |
| **U.S. Nuclear Regulatory Commission (NRC)** |
| NRC, 10 CFR Part 19, Notices, Instructions, and Reports to Workers, Inspections |
| NRC, 10 CFR Part 20 et al., Standards for Protection Against Radiation, Final Rule |
| NRC, 10 CFR Part 30, Rules of General Applicability to Domestic Licensing of Byproduct Material |
| NRC, 10 CFR Part 3, Specific Domestic Licenses of Broad Scope for Byproduct Material |

| |
|---|
| NRC, 10 CFR Part 35, Medical Use of Byproduct Material |
| NRC, 10 CFR Part 71, Packaging and Transportation of Radioactive Materials |
| NRC Information Notice No. 90-09, *Extended Interim Storage of Low-Level Radioactive Waste by Fuel Cycle and Materials Licensees,* February 5, 1990 |
| NRC Regulatory Guide 8.25, *Air Sampling in the Workplace* |
| NRC NUREG 1400, *Air Sampling in the Workplace* |
| NRC Report, NUREG 1516, Volume 9, *Consolidated Guidance About Materials Licenses, Program-Specific Guidance About Medical Use Licenses* |

| U.S. Food and Drug Administration (FDA) |
|---|
| FDA, 21 CFR 1000, Subchapter J, Radiological Health, through 1040.11 |
| FDA, Title 21, Part 892, Radiology Devices, Subpart B, Diagnostic Devices, 892.1000, Magnetic Resonance Imaging |
| FDA Title 21, Part 1040, Performance Standards for Light-Emitting Products |
| **American National Standards Institute (ANSI)** |
| For radioactive airborne effluent monitoring systems: Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities, ANSI Standard N13.1 |
| Specification and Performance of On-Site Instrumentation for Continuous Monitoring of Radioactive Effluents, ANSI Standard N 42.18 |
| Testing of Nuclear Air-Cleaning Systems, ANSI/ASME Standard N510 |
| American National Standard for the Use of Lasers, ANSI Standard 2136.1 |
| **State and Local Requirements** |
| For radioactive materials and radiation-producing equipment, the NIH is subject to Federal requirements and regulations. State and local regulations generally do not apply. |

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## Radiation Safety Regulatory Compliance:

Documentation: All NIH design and construction projects shall be in compliance with the following Federal regulations:

- The materials license that is issued by the NRC. Compliance with, and conditions of, the license are regulated by the NRC, consistent with the latest revisions of 10 CFR Part 20, 10 CFR Part 30.
- EPA regulations on NESHAPs, 40 CFR 61 Subpart I
- OSHA Ionizing Radiation Regulations 1910.96 and current Memorandum of Understanding between the OSHA and the NRC, December 23, 1989 (Enclosures B and C)
- U.S. Food and Drug Administration, 21 CFR 1000, Subchapter J, Radiological Health, through 1040.11
- The appropriate and current NIH Policy and Procedures Manuals

## Voluntary Guidelines, Recommendations, and Standards:

- American National Standards Institute
- American Association of Physicists in Medicine
- Conference of Radiation Central Program Directors, Inc.
- Health Physics Society
- Society of Nuclear Medicine
- International Commission on Radiological Protection
- National Council on Radiation Protection and Measurements

## Regulatory Compliance Issues:

NRC regulations and license conditions for air emissions: The materials license is issued by the NRC. Compliance with, and conditions of, the license are regulated by the NRC. Design requirements shall reflect the current Federal regulatory compliance standards. The latest guidance may be followed if not conflicting with current Federal regulatory requirements.

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# Appendix B

## Architect-Engineer (A/E) Checklist of Services

See Appendix A in the Facilities Development Manual

# Appendix C

**Room Data Matrix**

# NIH - RESEARCH LABORATORY

| | | | TYP. LABORATORY | BL3 MODULE | EQUIPMENT ROOM | TISSUE CULTURE LAB | DARK ROOM | RADIO-ISOTOPE LAB | ELECTRON MICROSCOPE ROOM | LASER ROOM | MAGNETIC RESONANCE IMAGING ROOM | X-RAY CRYSTALLOGR A-PHY ROOM | MASS SPECTROMETRY ROOM | AUTOCLAVE ROOM | STD ICE SUPPORT ROOM | COLD ROOM (STOR) | COLD ROOM (CHROMATOG RA-PHY) | WARM ROOM | GLASSWARE WASHING | CHEMICAL STORAGE | FLAMMABLE LIQUID STORAGE | GENERAL LAB STORAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | L.1 | L.2 | L.3 | L.4 | L.5 | L.6 | L.7 | L.8 | L.9 | L.10 | L.11 | L.12 | L.13 | L.14 | L.15 | L.16 | L.17 | L.18 | L.19 | L.20 |
| Architectural | Finishes | Walls | GW | GW | GW | GW | GW | GW | GW | GW | GW | GW | GW | GW | GW | PAP | PAP | PAP | GW | GW | GW | GW |
| | | Base | IV | IV | R | IV | R | IV | R | R | R | R | R | IV | R | NONE | NONE | NONE | R | NONE | 150 | R |
| | | Floor | SV/VCT | SV | VCT | SV | SV | SV | SV | SV | SV | SV | SV | SV | SV | PAP | PAP | PAP | VCT | VCT | HCS | VCT |
| | | Ceilings | ACT | GW | ACT | GW | ACT | ACT | ACT | ACT | ACT | ACT | ACT | ACT-2 | ACT | PAP | PAP | PAP | GW | GW | ACT | ACT |
| | Counter Tops | | PL | PL | | | PL | PL | PL | PL | PL | PL | PL | SS | N/A | N/A | N/A | N/A | | | N/A | N/A |
| | Ceiling Heights | | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2100 | 2100 | 2100 | 2850 | 2850 | 2850 | 2850 |
| | Door Width | Width | 1200 | 1200 | 1200 | 1200 | RDD | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 900 | 900 | 900 | 1200 | 1200 | 1050 | 1200 |
| | | Active Leaf | 900 | 900 | | | | SC | 900 | 900 | 900 | 900 | 900 | 900 | 900 | | | | | | | |
| | | Inactive Leaf | 300 | 300 | | | 300 | 1060 | 300 | 300 | 300 | 3400 | 300 | 300 | 300 | | | | | | | |
| | | Height | 2100 | 2100 | | | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | 2100 | | | | | | | |
| | Vision Panel | | YES | YES | YES | YES | NO | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES | NO | NO | NO |
| | Architectural Notes: | | | | | | | | | | | | | | | | | | | | | |
| Mechanical | Room Pressure | | NEG | NEG | NEG | NEG | NEG | NEG | NEG | NEG | NEG | NEG | NEG | NEG | NEG | EQUAL | EQUAL | EQUAL | NEG | 24 | 23 | EQUAL |
| | Temperature °C | | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 4 + 1 | 4 + 1 | 25-40 | 23 | 23 | 23 | 23 |
| | Relative Hum (%) | | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | 50/40 | N/A | N/A | N/A | 50/40 | 50/40 | 50/40 | 50/40 |
| | Exhaust Air | | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | YES | NO | YES | YES | YES | YES |
| | Return Air | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Filtration (%) | | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | N/A | 30, 90 | N/A | 30, 90 | 30, 90 | 30, 90 | 30, 90 |
| | Mechanical Notes: | | | | | | | | | | | | | | | | | | | | | |
| Plumbing | Cold Water | | YES | YES | NO | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | YES | NO | YES | YES | YES | NO |
| | Pure Water | | YES | YES | NO | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | YES | YES | YES | YES | YES | YES | NO |
| | Waste/Vent | | YES | YES | NO | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | YES | NO | YES | YES | YES | NO |
| | Steam | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | YES | NO | NO | NO |
| | Gases | | YES | YES | | NO | | YES | NO | NO | NO | NO | NO | NO | NO | NO | | | | | | |
| | Hot Water | | YES | YES | NO | YES | | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | NO |
| | Chilled Water | | YES | YES | NO | NO | L/C | YES | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Floor Drain | | NO | NO | NO | NO | YES | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES | NO | YES | NO | NO | NO |
| | Condensate | | NO | NO | NO | | NO | NO | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | YES | NO | NO | NO |
| | Plumbing Notes: | | | | | | | | | | | | | | | | | | | | | |
| Electrical | Ambient Illum (LX) | | 800-1100 | 80-1100 | 325-525 | 800-1100 | 500 | 800-1100 | | 50-1100 | 100-800 | 300-800 | 50-800 | 500 | 500 | 800 | 800 | 800 | 500 | 525 | 525 | 500 |
| | Task Illum (LX) | | 1100 | 1100 | | 1100 | | 1100 | | | | | 1100 | | NONE | | | | | | | |
| | Electrical Notes: | | | | | | | | | | | | | | | | | | | | | |
| Communication | Telephone | | YES | YES | | YES | YES | YES | YES | YES | YES | YES | YES | YES | | | | | | | | |
| | LAN | | | YES | | | YES | YES | YES | YES | YES | YES | YES | YES | | | | | | | | |
| | Tel. Near Door | | YES | | | | | | | | | | | | | | | | | | | |
| | Communication Notes: | | | | | | | | | | | | | | | | | | | | | |
| Special Req's | Chemical Fume Hood | | YES | YES | YES | | | YES | | | | | | | | | | | | | | |
| | Drench Shower | | YES | YES | | YES | | YES | YES | YES | YES | YES | YES | YES | | | | | | | | |
| | Eye-Wash | | YES | YES | | YES | YES | YES | YES | YES | YES | YES | YES | YES | | | | | | | YES | |
| | Automatic Sprinklers | | YES | YES | YES | YES | | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | | YES | YES |
| | Eye-Wash and Safety Shower | | YES | | | | | | YES | | | | YES | | YES | YES | YES | YES | YES | YES | YES | YES |
| | Flammable Liquid Storage Cabinets | | YES | | | YES | | | YES | YES | YES | YES | YES | YES | | | | | | | YES | |
| | Signage for Radioactive Uses and / or Storage | | YES | | | | | | | | | | | | | | | | | | | |

# NIH - VIVARIUM

| | | | LARGE ANIMAL HOLDING | SMALL ANIMAL HOLDING | PROCEDURE ROOM | NECROPSY | ANIMAL PREP | OPERATING ROOM | INTENSIVE CARE / RECOVERY | CAGEWASH (CLEAN, DIRTY EQUIP. AREA) | PHARMACY | SCRUB AND GOWN | SURGICAL SUPPLY & WORK ROOM | RAPIOGRAPHIC SUIT (X-RAY ROOM) CONTROL BOOTH | TREATMENT ROOM & EXAM ROOM | QUARANTINE ROOM | COLD ROOM | LOCKER ROOM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | V.1 | V.2 | V.3 | V.4 | V.5 | V.6 | V.7 | V.8 | V.9 | V.10 | V.11 | V.12 | V.13 | V.14 | V.15 | V.16 |
| Architectural | Finishes | Walls | CMU | CMU | CMU | CMU | CMU | CMU | CMU | CMU | GW | CMU | CMU | CMU | CMU | CMU | PAP | CMU |
| | | Base | IR | IR | IR | IR | IR | IR | IR | IR | IV | IR | IR | IR | IR | IR | NO | IR |
| | | Floor | RE | RE | RE | RE | RE | RE | RE | RE | SV | RE | RE | RE | RE | RE | PAP | RE |
| | | Ceilings | GW | GW | GW | GW | GW | GW | GW | GW | ACT-2 | GW | GW | GW | GW | GW | PAP | GW |
| | Ceiling Height | | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 | 2400 | 2400 | 2400 | 2850 | 2400 | 2400 | 2100 | 2400 |
| | Door Width | | 1050 | 1050 | 1050 | 1050 | 1050 | 1200 | 1050 | 1050 | 900 | 1050 | 1050 | 1050 | 1050 | 1050 | 900 | 900 |
| | Vision Panel | | YES | YES | NO | NO | YES | SPECIAL | YES | YES | NO | YES | YES | NO | YES | YES | YES | NO |
| | Tinted Glass Panels | | | | | | | | | | | | | | | | | |
| | Architectural Notes: | | | | | | | | | | | | | | | | | |
| Mechanical | Room Pressure | | NEG | NEG | NEG | 23 | 23 | 20% | NEG | NEG | POS | POS | POS | POS | NEG | NEG | EQ | NEG |
| | Temperature °C | | VARIABLE | VARIABLE | 23 | 23 | 23 | 23 | VARIABLE | 23 | 23 | 23 | 23 | 23 | 23 | VARIABLE | 23 | 23 |
| | Relative Hum (%) | | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | 30-70 | N/A | 30-70 |
| | Exhaust Air | | YES | YES | YES | YES | YES | YES | YES | YES | NO | NO | NO | NO | YES | YES | NO | YES |
| | Return Air | | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES | NO | NO | NO | NO |
| | Filtration (%) | | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | 30, 90 | N/A | 30, 90 |
| | Mechanical Notes: | | | | | | | | | | | | | | | | | |
| Plumbing | Cold Water | | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | YES |
| | Hot Water | | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | YES |
| | Treated Water | | YES | YES | YES | NO | NO | NO | NO | YES | NO | NO | NO | NO | YES | NO | YES | YES |
| | Chilled Water | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Waste/Vent | | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | NO | YES |
| | Floor Drain | | YES | NO | NO | YES | NO | YES | YES | YES | NO | NO | NO | NO | NO | YES | NO | YES |
| | Steam | | NO | NO | NO | | NO | NO | NO | YES | NO | NO | YES | YES | NO | NO | NO | NO |
| | Condensate | | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| | Plumbing Notes: | | | | | | | | | | | | | | | | | |
| Electrical | Ambient Illum (LX) | | 270-800 | 270 | 1100 | 1100 | 1100 | 1100-2200 | 270 | 800 | 750 | 500 | 500 | 50-500 | 1100 | 270-800 | 500 | 400 |
| | Task Illum (LX) | | | | 1100 | 1100 | 1100 | | EXAM 1100 | | 1100 | 800-1100 | 1100-1600 | | | 500 | | NO |
| | Electrical Notes: | | | | | | | | | | | | | | | | | |
| Communication | LAN | | YES | YES | | | | | | | | | | | | | | |
| | Telephone | | | | | YES | | YES | YES | YES | | YES | YES | | YES | YES | | YES |
| | Voice Communication Fire Alarm System | | YES | YES | | | | | | | | | | | | | | |
| | Communication Notes: | | | | | | | | | | | | | | | | | |
| Special Req's | Strobe Emergency Warning Light | | YES | YES | | | | | | | | | | | | | | |
| | Hose Bid | | YES | YES | | | | | | | | | | | | | | |
| | Notes: | | | | | | | | | | | | | | | | | |

# Appendix D

## A. Bethesda Campus Application of the DRM

A.1 Introduction: Appendix 1 presents clarification of specific applications of the BAS Chapter of the DRM as applied to the Bethesda Campus of NIH as well as the following satellite campuses/sites managed from the Bethesda Campus:

- Twinbrook.
- Poolesville.
- Ft. Detrick.
- Rocky Mountain Laboratories.

A.2 General Requirements: Consult with the designated representative from NIH DPM for requirements for using the campus network, alarming integration with the Help Desk, and when applicable, integration to existing systems. Coordinate with NIH TST relative to Vivarium Environmental Monitoring and Data storage.

A.2.a Scope: Utilities at the Bethesda Campus are provided from a central utility plant. Coordinate with NIH DPM UOB for building utilities monitoring. Electrical power, chilled water, and steam, shall be connected to independent monitoring systems (SCADA for electrical and Utility Monitoring System). Some devices (flow meters for instance) may be tied into both systems upon direction NIH DPM.

A.3 Standardization: The following site-specific standards apply to the Bethesda Campus. These are available at:

- Alarm handling procedures specification.
- NIH Point Naming.
- Supervised Objects Specification.
- NIH Specific Requirements.
- Central Archiving Software.
- Remote Alarming Notification.

A.4 General Infrastructure Requirements: BAS's installed on the Bethesda Campus shall use the existing FACNet .Ethernet LAN installed by NIH CIT. This network shall support other systems such as security, Vivarium Environmental Monitoring, Data, etc. IP addresses of primary panels shall be assigned by NIH CIT.

BAS's installed at satellite sites shall use the same network with remote connection as configured by NIH CIT.

A.4.a Integration With Existing Systems: Existing systems at Bethesda are predominantly the Siemens Building Technologies Apogee System 600 and Johnson Controls Inc. Metasys Extended Architecture. Consult with NIH DPM for detailed requirements of the required integration.

A.4.a.1 Primary Controller LAN: Illustrative examples of a Primary Controller LAN include Siemens BLN or JCI N1.

A.4.a.2 Secondary Controller LAN: Illustrative examples of a Secondary Controller LAN include Siemens FLN or JCI N2.

A.4.b Servers:

A.4.b.1 Description: Server infrastructures that exist at the Bethesda Campus include Siemens Apogee and JCI Metasys. New systems that extend the coverage of these existing systems shall include applicable upgrades to the server environment required to support the new extension.

A.4.c Vivarium Monitoring Workstations: Coordinate with NIH TST for required computers (typically not required), BAS and Data LAN connections, and trend/point requirements for all Vivarium facilities installed at the Bethesda Campus or satellite facilities.

A.4.d Intranet Remote Connections: Coordinate with NIH CIT for LAN configurations and access rights for remote access.

A.5 Building Level Requirements: Coordinate with NIH DPM UOB for .building utilities monitoring. Much of the monitoring required here shall be tied into the NIH Campus Energy Management System. In some cases, devices like flow meters can be tied into both the campus wide energy management system as well as the BAS.
A.5.a Laboratories with VAV Hoods: All new installations of VAV fume hoods shall incorporate high speed electronic actuators on the fume hood exhaust control box as well as all associated airflow/pressure tracking controls.

A.5.b Critical Laboratories: There shall be not fireman's override controls on non-JCAHO systems at Bethesda or satellite sites.

A.5.c All Animal Holding Room: Space and humidity sensors in Bethesda and satellite sites shall be located in the general exhaust stream as close as practical to a representative room inlet. Ensure sensor penetrations into duct are well sealed and that the sensor is representative of the macro-environment of the animal holding room.

A.5.d Supply Air Systems: Supply air systems that do not serve JCAHO accredited spaces shall not include smoke or heat detection and corresponding shut down that would be required by NFPA.

A.5.d.1 Scheduling: Laboratory spaces shall not include scheduled variations to temperature or airflow.

A.5.e Building Steam Connections to Campus System: The steam to buildings on the Bethesda Campus shall come from the campus steam system and immediately be reduced in pressure. Coordinate with NIH Utility Operation Branch for the meters and monitoring of the steam service.

A.5.e.1 Campus Chilled Water Connections: The chilled water to buildings at the Bethesda Campus shall come from the campus chilled water system. The design shall include building pumps, a decoupling bridge, and a building valve. Coordinate with NIH UOB for projections as to the extremes of potential pressure differentials probable at the building and provide a valve selected for effective control across that range of pressure differentials.

A.5.f Control Air Systems: The campus air system shall be used as the primary source for control air. Redundant local compressors shall provide the required airflow if the campus air system fails

A.5.g Fume Hoods: Two systems that have been qualified for use at NIH include Siemens Building Technologies FHC and associated LRC, and Phoenix Celaris.

A.6 Control System Architecture: One master architecture diagram shall be maintained for each installed manufacturer that is inclusive of all installations of that system on campus. Design documents shall include the requirement to update this.

A.6.a Points List: One master points list shall be maintained for each installed manufacturer that is inclusive of all installations of that system on campus. If this can be queried from the BAS server database, this will suffice.

A.6.b Primary Controller: The following are illustrative examples of Primary Controllers at Bethesda and satellites:

- SBT Modular Building Controller or Modular Equipment Controller with expander modules allowed. The key requirement is for the MBC or MEC processor to fully control all sequences of points attached to it.
- JCI packaged NAE with a dedicated DX 9100 and no other devices on the N2.

A.6.c Secondary Controllers: Illustrative examples of secondary controllers at the Bethesda and satellite campuses include:

- SBT TEC, RPC, LRC, DPMs, DEMs.

- JCI UNT, DX9100, DX9200, VMA, AHU, LN Series.

A.6.d Flow Meters: All incoming building utilities metered values shall be displayed on both the general building graphics used by operating personnel, and the energy management graphics. All incoming supply domestic water, chilled water and steam metered values, as well as chilled water supply and return temperature and pressure values shall also be mapped to and be functional with BAS historical utility database. The following shall apply to the Bethesda Campus. Electric metering requirements will be covered in Chapter 10 Electrical.

- Steam metering shall be insertion vortex shedding device. Turbine meters shall be considered only in extreme cases, or as additional supplemental devices to capture minimum flow in extreme cases.
- Chilled water shall be clamp on ultrasonic device.
- Domestic water shall be magnetic metering device. Clamp on ultrasonic device for line sizes in excess of 150 mm can be considered.

A.6.e Actuators: New installations at Bethesda and satellite campuses shall use electronic actuators unless specifically directed otherwise by the Project Officer. This shall include both slow acting (30 sec and above) and fast acting (<3sec.). One exception to this is for high torque actuators on main supply air handling units and exhaust fans that serve containment and high containment applications.

A.6.f Compressed Air Systems: Campus compressed air shall be distributed to the building from the campus system on the Bethesda campus. Tie in to the building standby skid shall be downstream of the compressors and receiver and upstream of driers and filters. Ensure, standby compressors are adequately exercised.

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# Appendix

E

## E.1 Calculating the Ventilation Rate for the Removal of Contaminants from Biomedical Laboratories by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health.

Consultants that address the indoor air quality using the dilution method must fully understand the shortcomings. Containment is preferred over dilution where practical. When dilution is used, concentration levels can vary greatly depending on air flow patterns within a room and the nature of the source or the contaminant. Contaminant is never evenly distributed within a room. The following equation is based evenly distribution. So, if used consideration shall be given to the fact that the results are only the average when supply air is mixing evenly with the contaminant. In practice, most areas within a room will have higher or lower concentrations.

Where:

C $C = C_0 e^{-[V_{removed} / V_{room}]}$ = the Ending Concentration of the Vapor in the Closed Space or Room, which Ending Concentration, measured in ppm, resulted from the purging activities:

$C_0$ = the Initial Concentration of the Vapor in the Closed Space or Room that is to be reduced by purging, also measured in ppm;

$V_{removed}$ = the Air Volume that has been withdrawn from the Closed Space or Room, measured in any suitable volumetric units, usually in cubic feet (ft); and

$V_{room}$ = the Volume of the Room, measured in the same volumetric units as $V_{removed}$, which is usually in cubic feet ($ft^3$).

A real example of the use of the above equation would be if a consultant needs to assess the Aroom volumes≈ of air that must be withdrawn from (purged) a room in order to reduce the concentration of any volatile substance in the ambient air of that room buy 90% or by 99%. In order to achieve some well defined and specific decrease in the Astarting ambient concentration≈ of some unidentified volatile substance. From the perspective of the applicable formula listed above, we must view this as asking for a value of An≈, where An≈ is the number of Room Volumes for which -- once this volume of ambient, volatile filled air had been removed from the space -- would result in a situation where the residual room concentration of that volatile would be at or below the identified target concentration level. Specifically, seeking an exponent of Ae≈ in the following general format:

$-\frac{n V_{room}}{V_{room}}$ Clearly, the $AV_{room}$≈ terms will cancel out, and we are left with the simple exponent value of n; and we can, therefore, see that formula evolves to the following:

of n, as a $C = C_0 e^{-n \frac{V_{room}}{V_{room}}} = C_0 e^{-n}$ The task for the consultant is simply to determine the value number of Room Volumes, that corresponds to: (1) a decrease in the ambient concentration to a level that is only 10% of the starting value (i.e. the ending concentration, $C_{90\%}$, has the value $0.1C_o$]; and (2) a decrease in the ambient concentration to a level that is only 1% of the starting value [i.e. the ending concentration, $C_{99\%}$, has a value, $0.01C_o$].

For a 90% reduction in the concentration: $C_{90\%} = 0.1\ C_0 = C_0 e^{-n_{90\%}}$

$$0.1 = e^{-n_{90\%}}$$

$$\ln 0.1 = -n_{90\%} = -2.303$$

$$n_{90\%} = 2.303$$

For a 99% reduction in the concentration:

$\ln 0.01 = - n_{99\%} = - 4.605$ To achieve specified reductions in the ambient concentrations of any volatile substance, one must purge the following number of *Room Volumes* to attain the identified target reduction in the ambient room concentration level:

$n_{99\%} = 4.605$

| Target Reduction as a Percentage | Number of Room Volumes |
|---|---|
| 90% | -2.3 |
| 99% | -4.6 |

E.2 Calculating Minimum Separation Distance Between Intakes And Exhausts by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health.

Use of an expert consultant to do either wind tunnel or computational fluid dynamics (CFD) air dispersion modeling is highly recommended to analyze and make recommendations on these factors. Where this is done, it must assess the possibility of re-entrainment of any and all near-by exhausts into any and all near-by intakes. For example, where a new building is being designed, the CFD or wind tunnel analysis considers the impact of the new building as well as near-by existing buildings and other new and existing obstacles and considers new and existing exhaust relative to new and existing intakes.

When using CFD, certain factors shall be considered in the evaluation of external flow type scenarios. First, the size of intakes, chimneys, etc. in an external flow problem in comparison to the overall size of the solution domain considered is usually small. In terms of creating computationally tractable problems, it is difficult to resolve the grid close to these sources of heat, momentum, or concentration without being subject to numerical diffusion. To highly minimize the numerical diffusion augments and the effective viscosity, the solution domain shall use advance grids (meshing) or higher order differencing schemes. Second, the most widely accepted turbulence model used in CFD, namely the k-turbulence model, over-predicts turbulent viscosity in regions of decelerating flow. Therefore, the model shall be based on the assumption that the turbulent viscosity is the same in all three coordinate directions; that is, the viscosity is orthotropic. This is untrue for highly curved, swirling, or buoyant flows. All of these forms of flow regime are typically present in external flows of interest to some extent. The effects of this can be offset by alternatives, but they are subject to various problems.

To alleviate the concerns from the numerical simulation aspect, a series of grid refinement tests shall be carried out to minimize the effect of numerical diffusion in this calculation. The numerical diffusion in three dimensions can be approximated, using Patankar (1980), as:

$$\Gamma = \rho V \left[ \frac{d_x d_y n_x n_y}{d_x n_x + d_y n_y} + \frac{d_y d_z n_y n_z}{d_y n_y + d_z n_z} + \frac{d_z d_x n_z n_x}{d_z n_z + d_x n_x} \right]$$

Where:

$\Delta$ = fluid cell density
V = fluid speed
($n_x$, $n_y$, $n_z$) = unit vector // to flow
$d_x$, $d_y$, $d_z$ = cell dimensions

Owing to the complex nature of this, the approach and the methodology of these calculations need to be agreed upon between the NIH and the contractor.

The results of such tests will be approved by the NIH. If it is found that the numerical diffusion issue cannot be addressed in a single model, then a "zoom-in" approach will be used. In this zoom-in approach, an initial model will be constructed that will represent the laboratory building plus all the surrounding buildings. The results from this initial simulation will then be taken from a volume immediately surrounding the laboratory building and applied to a second model that represents only the laboratory building and its immediate surroundings. If necessary, grid refinement tests will also be applied to the second model to ensure that numerical diffusion is eliminated as much as possible.

The following will be considered in this study. (Details and clear methodology for the calculations will be provided by the NIH. Contact Farhad Memarzadeh, Ph.D., P.E., ORF, for assistance and guidance.)

- A methodology for the calculation of reentrainment into the building.
- A methodology for the calculation of odor and health threshold limits (in $mg/m^3$) and their comparison against the numerical analysis data.
- A methodology for the determination of pass/fail criteria based on the threshold limit.
- Alternate wind speeds and directions from appropriate wind rose data.

E.3 Fume Hood Testing and Alarms System by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health.

Fume hoods in new laboratory facilities shall have a pressure-independent flow-monitoring device connected to a local audiovisual alarm within the laboratory area. For existing facilities, the implementation of airflow devices for fume hoods occurs during the renovation phase. When the fume exhaust falls below a preset safety level, the alarm will sound and the alarm light will come on.

All parts that are to be in contact with vapors/fumes in the hood, i.e., the sensing device, wiring, etc., shall be chemically resistant. All alarm systems shall be UL approved. There shall be a means to shut off the audible alarm to reset. The alarm shall have an internal timer so that the audible alarm is reactivated after a specified time (adjustable between 5 minutes and 15 minutes). The alarm shall have the capability to set the controller's setpoint to the safety level desired. There shall be a means for setting the controller's setpoint to the exhaust level desired. This adjustment shall be "internal" so that it is not readily adjustable by operating personnel. Upon return to normal flow, the alarm shall sound again until reset.

The ACGIH Guidelines are referenced in the DRM for fume hood testing. The ACGIH requirements do not specifically address all testing issues required by the NIH. The following criteria shall be used for testing fume hoods in NIH buildings:

The fume hood manufacturer, no later than 30 days after receipt of the order, shall provide to the owner the use of a state-of-the-art fume hood test facility meeting the requirements of the latest SMACNA Standard LF 10.

The hood manufacturer shall conduct modified ASHRAE Standard 110, 1995, protocol of 1,800 mm hood of similar design to the type specified. The bypass shall be designed so that face velocity does not exceed the maximum as the sash is lowered in a variable volume hood. Variable volume fume hood protocol of 1,800 or 1,200 mm shall be tested in accordance with the Modified ASHRAE 110 Test for minimum baseline requirements. The manufacturer shall provide a fume hood control system at its state-of-the-art test facility meeting the requirements of the latest SMACNA standard LF 10 on its cost for acceptance by the NIH prior to the delivery of hoods for installation. The minimum of 50% installed hoods at site will be again offered for testing on site by the contractor after installation and building balance prior to occupancy. The contractor shall arrange for tests to be conducted by an NIH-approved independent testing contractor. The specifications shall clearly identify the type of measurement devices that test a constant face velocity, such as hot wire anemometer, heated thermocouple anemometer, impact tube and side wall or other static tap, pitot tube, etc., or measure volume or mass flow rate using devices such as orifice and differential pressure measurement system, nozzle and differential

pressure measurement system, turbine flow meter, swirl flow meter, and vortex shedding meter. A hood of design similar to the type specified in the ASHRAE Standard 110 will have the parameters described in the next paragraph.

Fume Hood Testing: Note: This item must be included in the balancing specifications, the fume hood control specifications, and the hood specifications.

E.3.1 Fume Hood Containment Testing (Onsite): Laboratory areas and variable volume fume hoods shall be tested as installed to assess the level of containment. The test identified below was created by Farhad Memarzadeh, Ph.D., P.E., of NIH in 1997 and revised by Memarzadeh and Brightbill in 1999 and shall be performed during static and dynamic conditions. Testing shall be conducted as outlined below for 50% of the hoods provided in the project. Tests shall be characterized and referred to in two basic categories, "Static" and "Dynamic". "While elements of both static and dynamic testing exist in both test categories, these names are generally used for reference.

E.3.1.a Static Testing: Testing shall be conducted in accordance with ASHRAE 110 - *Method of Testing Performance of Laboratory Fume Hoods* with the following modifications. This is primarily a test of the hood and laboratory configuration.

Hoods will be tested with simulated apparatus. This apparatus will consist of two each 3.8 L round paint cans, one 300 mm x 300 mm x 300 mm cardboard box, and three each 150 mm x 150 mm x 300 mm cardboard boxes. These items will be positioned from 150 mm to 250 mm behind the sash, randomly distributed, and supported off the work surface by 50 by 50 mm blocks.

- The test gas will have a 6 L/min flow rate.
- Each test duration will be 5 minutes.
- Acceptable test results shall not exceed 0.05 ppm.
- At the conclusion of each 5 minute test, there will be three rapid walk-bys at 300 mm behind the manikin. Each two walk-bys will be spaced 30 seconds apart. If there is a rise in test gas concentration, it cannot exceed 0.10 ppm and must return to 0.05 ppm within 15 seconds.
- There will be a minimum of three and a maximum of five persons in the test room during the test procedure.
- Representatives of the NIH will witness the tests.

E.3.2 Dynamic Testing: Dynamic testing primarily tests the dynamic performance of the fume hood control system. This group of tests measures hood performance parameters through various dynamic "events." Events shall include four sash movements up and down across differing ranges: 25-100 percent and 50-100 percent, sash movements of other hoods on the exhaust duct, walk-bys in front of the hood, and opening and closing the laboratory door commensurate with a person entering and exiting the room. Hood parameters to be determined for each event are defined as follows (refer to Figure F.16.3.3 below for a graphical representation of some parameters):

- Measured Face Velocity (FVm expressed in m/s): Face velocity measured in the plane of the sash. Samples shall be recorded at no less than 10 Hz. Sensing methodology shall have an internal time coefficient of no more than 100 ms.

  Definitions:

  a. The internal time constant (ITC) is the amount of time it takes the sensor to respond 63 percent of the way to a step change.
  b. The response time is the length of time to get to within the stated accuracy of the sensor.
  c. Response time = ITC x 3 or 5 depending on the accuracy. Example: If the response time is 200 ms, the ITC = 40-70 ms.

  There shall be a point sensor located in the middle of the face opening when the sash is at the lowest position during the tested event. No fewer than three point sensors shall be used. Averages shall be calculated for any point in time

to assess overall measured face velocity; however, individual sensor samples shall be used in calculating turbulence intensity (TI).

- Total Exhaust Airflow (TEF expressed in L/s): Total exhaust flow measured in the main exhaust duct leaving the hood. This parameter shall be recorded at no less that 10 Hz. The sensing methodology used for the recorded data shall represent the total airflow through the full range of flows and be validated by independent multipoint measurement. If the fume hood control system uses a flow-sensing element, that element may be used assuming it can be calibrated across the full range of flow. Sensing elements must have an internal time coefficient of no more than 20 ms.
- Variable Face Area (FAv expressed in meters): Face area of the hood that varies as the sash is moved within specified limits.
- Fixed Face Area (FAf expressed in meters): Face area of the hood with sash at minimum position (minimum position shall correlate with the minimum bypass flow through the hood).
- Hood Airflow Leakage (HAL expressed in L/s): The difference in airflow between the measured airflow through the face (at minimum position) and the total airflow measured in the exhaust duct.
- Calculated Face Velocity (FVc): Face velocity determined from the following equation: (TEF-HAL x 1 000)/(FAv + FAf).
- Steady State Face Velocity (SSFV): The average of all sampled face velocities for a 5 second period. Two SSFVs will be determined for both measured face velocity and calculated face velocity; one before the event (SSFVb) and one after (SSFVa). The SSFVa will start 2 seconds after the end of TSS. The second suffix of m for measured and c for calculated shall be used to indicate the type of assessment.
- Face Velocity Baseline (FVBL): The average of SSFVa and SSFVb.
- Control Linearity (CL expressed in %): Abs (SSFVa-SSFVb)/(FVBL) x 100.
- Time to Steady State ($TSS_{10}$ and $TSS_5$ expressed in seconds): The elapsed time from the initial sash movement until the FVc reaches and stays within ±10 percent or ±5 percent of FVBL (as indicated by the subscript).
- Face Velocity Overshoot/Maximum Deviation (FVO expressed in percent): Calculated using the Calculated Face Velocity sample farthest from the FVBL (FVf) throughout the test per the following equation: (Abs (FVf-FVBL)/FVBL) x 100. Samples include initial face velocity deviation immediately following the sash movement as the controls initially respond to the movement of the sash.
- Response Time Constant (RTC expressed in seconds): Elapsed time between initial movement of the sash and the initial subsequent movement of the exhaust valve.
- Steady State Deviation (SSD expressed in %): Face velocity variation from SSFVa or SSFVb as applicable. Calculated using the farthest sample from the applicable SSFV (FVf) using the following equation: (Abs (FVf-SSFVx)/SSFVx) x 100.
- Controllability (expressed in mV/mm): Describes controller response to changing sash position, i.e., controller's response signal change per unit distance of sash movement.
- Sash Position (SP expressed in mm): For vertical sashes, vertical distance from the sill of the hood to the bottom of the sash. The minimum sash position shall correlate with the position of the sash when the minimum flow through the hood is all through the face. Maximum sash position shall be defined as a distance of 550 to 650 mm. This parameter shall be recorded at no less than 10 Hz.
- Controller Output (CO expressed in volts): Control output to the controlling exhaust air valve. This parameter shall be measured and recorded at no less than 10 Hz.
- Turbulence Intensity (TI expressed in m/s): Calculated root mean square of the fluctuating face velocity determined using FVm. This value shall be calculated for each of the steady state conditions preceding and following each event. This shall be correlated with a "box leakage factor" of the installation using the *Methodology for Optimization of Laboratory Hood Containment* (MOLHC) by NIH Office of Research Services, Farhad Memarzadeh, Ph.D., P.E., principal investigator. While this value does not have a pass/fail requirement, it is the fundamental indicator of containment and therefore shall be clearly reported.

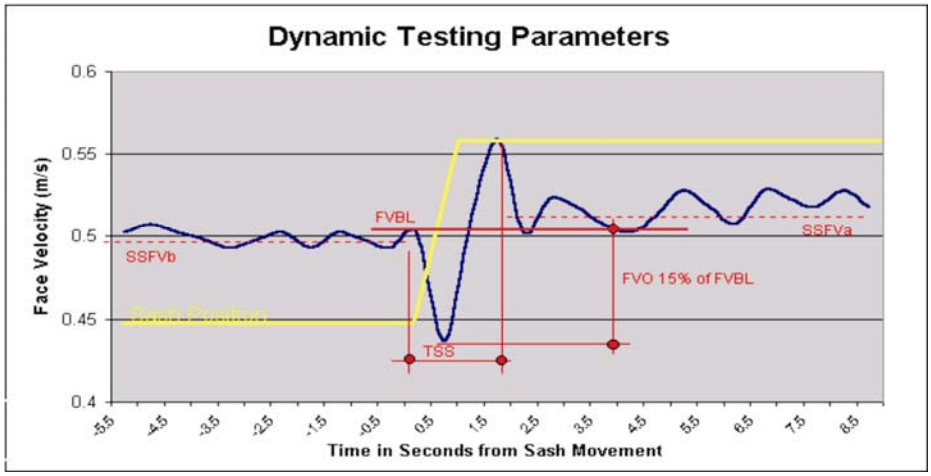



Figure E.3.A Dynamic Testing Parameters

E.3.3 Parameter Performance: Parameter performance requirements:

- Face Velocity Baseline (FVBL): 0.51 m/s ± .05 m/s
- Control Linearity (CI expressed in %): < 2%
- Time to Steady State$_{10}$ (TSS$_{10}$ expressed in seconds): <2 seconds
- Time to Steady State$_{5}$ (TSS$_{5}$ expressed in seconds): <3 seconds
- Face Velocity Overshoot/Maximum Deviation: <15%, which means at no point throughout the test shall a sample be recorded <0.43 m/s or >0.59 m/s
- Response Time Constant (RTC expressed in seconds): <0.5 seconds
- Steady State Deviation (SSD expressed in %): <5% assessed using calculated face velocities
- Controllability (expressed in mV/mm): >12 mV/25.4 mm

E.3.3.a Alternate Parameter Performance Requirements: The following performance parameters are alternate requirements that can be used in assessing acceptable dynamic responses:

- Face Velocity Baseline (FVBL): 0.51 m/s ± .05 m/s.
- Calculated Face Velocity (FVc): All samples >0.255 m/s and <0.89 m/s, meaning that at no time during the event shall the calculated face velocity be outside that range. Any sample recorded beyond that range will result in assessing the response as unacceptable.
- Control Linearity (CI expressed in %): <2%.
- Time to Steady State$_{10}$ (TSS$_{10}$ expressed in seconds): <1.6 seconds.
- Time to Steady State$_{5}$ (TSS$_{5}$ expressed in seconds): <2 seconds.
- Response Time Constant (RTC expressed in seconds): <0.5 seconds.
- Steady State Deviation (SSD expressed in %): <5% assessed using calculated face velocities.
- Controllability (expressed in mV/mm): >12 mV/25.4 mm.
- Test Execution: Testing agency shall be equipped to execute the testing and assess all performance parameters on site the day of the test. Data acquisition of required parameters shall be simultaneous.
- Test Documentation: All testing, calculated, and recorded parameters shall be presented in a report that shows the recorded parameters graphically and tabulates and summarizes all the results. Performance of the hood, the hood controls, and the laboratory in general shall be described and summarized.

Note: Fume Hood Control Testing (Offsite-Mockup) must be included only in the control manufacturer's specifications.

E.3.4 Fume Hood Control Testing (Offsite-Mockup): The manufacturer of the proposed fume hood control system shall mock up a fume hood installation and demonstrate the performance of its system to validate that they can meet the requirements specified herein. The offsite test shall include all parameters under the control of the control system (FVBL, TSS, CL, RTC, SSD, and Controllability). It is not necessary to mock up the installation and assess TI. Events to be tested off site include all specified sash movements on the hood being tested. Walk-by and door-opening affects are not required for the offsite test.
The testing shall be accomplished by an independent testing agency approved by the A/E and NIH. Reports shall be provided with the laboratory control submittals, and no approval will be given for the fume hood control system until documentation of successful demonstration of the performance requirements is submitted.

E.4 Harmonic Control in Electric Power Systems by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health.

E.4.1 Voltage Sag Concerns: Despite the main advantages provided by VSD's, the concern for nuisance tripping during voltage sag conditions remains. This power quality concern involves the control sensitivity to short-duration voltage sags and momentary interruptions. Actually, many different kinds of controls, and even motor contractors, are sensitive to these voltage sags. Voltage sags caused by faults on the power system represent one of the most important problems that can be experienced by the NIH with sensitive loads. Whenever there is a fault on the transmission or distribution system serving the NIH facility (faults cannot be completely avoided regardless of the system design), there will be either a voltage sag or an interruption. If the fault occurs on a parallel-distribution feeder circuit or on the transmission system, there will be a voltage sag that lasts until the fault is cleared by some protective device (typically 3-30 cycles depending on the fault location). A method of predicting the likelihood of faults in a certain region along with knowledge of equipment sensitivity can be used to determine an "area of vulnerability". A combination of computer short-circuit simulations and lightning performance analysis shall be used to determine the affected area. The VSD controls shall be designed to handle these voltage sag conditions without tripping. The specifications contain no-ride-through capability. This is an important consideration when VSD's are applied in critical processes such as that of the NIH, where nuisance tripping can cause significant problems. The A/E shall evaluate the level of sensitivity of the controls to voltage sags. If such concern exists, applying power conditioning to the controls themselves will be considered. Feroresonant transformers can handle voltage sags down to approximately 60 percent of the nominal voltage. This is sufficient to handle virtually all voltage sags caused by single line-to-ground faults on the power system. If additional protection is needed, the controls can be protected with an UPS system, which can handle complete interruptions in the input signal.

E.4.2 Transient Overvoltage Concerns: Transient overvoltage occurs in connection with capacitor switching. Each time a capacitor is energized, a transient voltage oscillation occurs between the capacitor and power system inductance. The result is a transient overvoltage that can be as high as 2.0 V per unit (of the normal voltage) at the capacitor location. The magnitude is usually less than 2.0 V per unit as a result of dampening provided by system loads and losses. The transient overvoltage caused by capacitor energizing is generally not a concern to PEPCO because its magnitude is usually below the level at which surge-protective devices operate (1.5 to 2.0 V per unit). However, these transients can be magnified at the NIH facility if the NIH has low-voltage capacitor banks for (displacement) power factor correction. The A/E shall check for this matter. When the frequency of a transient overvoltage matches the series-resonant frequency of the NIH transformer coupled with PEPCO capacitor(s) at the East Substation, a low-impedance, high-current (at the resonant frequency) condition results. As this large current passes through the NIH transformer, it induces a large voltage "drop" that passes through zero voltage to create a large voltage of opposite sign (because of a phase-angle change) at the resonant frequency. The VSD and the NIH paralleled capacitor (and their surge protection devices) then see this magnified voltage (compared to distribution feeder voltage). When the resonant-frequency current completes its path to ground through the capacitor, the voltage experiences a "boost" to the ground-reference voltage. The magnification of capacitor-switching transients is most severe when the following condition exists: The capacitor switch on the higher voltage system is much larger (kVAR) than the capacitor at the low-voltage bus. Generally, this situation occurs most frequently for substation switching. The frequency of oscillation that occurs when the high-voltage capacitor is energized is close to the resonant frequency formed by the stepdown transformer in series with the low-voltage capacitor. There is little resistive load on the low-voltage system to provide dampening of the transient, as is usually the case for industrial plants (motors do not provide significant damping of these transients). It is not uncommon for magnified transients at low-voltage

capacitors to range from 3.0 to 4.0 V per unit. These transients have significant energy associated with them and are likely to cause failure of protective devices, metal oxide varistors (MOV's), electronic components (silicon-controlled rectifiers, etc.), and capacitors. VSD's are particularly susceptible to these transients because of the relatively low peak-inverse voltage ratings of the semiconductor switches and the low-energy ratings of the MOV's used to protect the VSD power electronics. The following shall be evaluated and identified in the specifications to control these magnified transient overvoltages: using vacuum switches with synchronous closing controls to energize the capacitor bank and control the capacitor-switching transient; providing high-energy MOV protection on the 480 V buses (the energy capability of these arresters shall be at least 1 kJ); or using tuned filters for power factor correction instead of just shunt capacitor banks (the tuned filters change the frequency response of the circuit and usually prevent magnification problems; this solution combines power factor correction, harmonic control, and transient control).

E.4.3 Electromagnetic Interference and Radio Frequency Interference Concerns: IEEE Standard 519, *Recommended Practices and Requirements for Harmonic Control in Electric Power Systems,* recommends limits for voltage distortion and harmonic current resulting from nonlinear loads. However, the IEEE standard is not intended to cover the effects of radio frequency interference (RFI). As a result, specifications will occasionally refer to Federal Communications Commission (FCC) *Rules and Regulations*, Volume 2, Part 15, Subpart J, Class A (referred to as "FCC rule") to establish limits on electromagnetic emission for VSDs. The FCC rule was printed in October 1982 primarily for computing devices. Computers generate RF energy and possibly cause interference with nearby equipment if misapplied. Generally, the rule sets conducted and radiation RF limits for electronic devices using timing signals or digital techniques with pulse rates in excess of 10 000 pulses per second. Technically speaking, VSD's with high-frequency timing circuits conform to this description, although they are not intended as a computing device described in the FCC rule. The primary and more significant source of electromagnetic interference (EMI) from a VSD stems from the power circuits, and, in this respect, drives become an incidental radiation device. The only requirement for incidental radiation devices in the FCC rule is that they shall be operated so that the RF energy emitted does not cause harmful interference. If so, the operator must eliminate the interference. All VSD's, regardless of the manufacturer, will produce electromagnetic emission to some degree. Primarily, these emissions are due to the steep wave fronts and very rapid switching of power semiconductors in the VSD. Typically this occurs when transistors, GTO's, or other "fast devices" are gated on and off in DC chopper circuits and inverter power circuits for PWM, current source, and six-step drives. Typically, conductors to the VSD's and motor act as an antenna and radiate the RF energy into the media. Therefore, it is possible for RF to be induced into nearby antennas and other conductors and be carried to the loads in that circuit. Holding a portable AM radio near a power outlet in close proximity to an EMI source can be evidence of this situation. Distributive digital control (DDC) systems, medical alarms system and equipment, telecommunication services, and other electronic equipment utilizing very high frequencies may experience noisy interference or malfunctions when subject to EM/RF energy. The specification shall clearly outline the corrective measures required. The first and foremost corrective measure to avoid problems associated with EMI is proper routing of the drive conductors in separate metallic conduits (even separate raceways if practical) as remote as possible from any other conductors or suspect equipment. Usually, this will be sufficient to avoid EMI problems. EM/RF filters can be engineered for a system to trap or inhibit high-frequency emissions into power system conductors. However, because of the nature of EMI, the effectiveness of any filter is highly sensitive to where it is installed. Further, it is not certain that the filter will correct the problem even though it may meet FCC limits. Most manufacturers will include this footnote with their literature: "Filters are expensive and usually require additional space. It is recommended that they be furnished only when they are specifically required to avoid or solve a problem after exhausting all proper installation methods. In addition, filters are an additional component and must be considered in the overall reliability of a power system". To contain RF radiation through the media from the VSD, complete shielding using a metallic enclosure generally is required. This will usually contain most of the radiated RF to a reasonable distance.

E.5 Calculation Protocols for Canopy Hoods over Autoclaves: NIH Local Exhaust Ventilation (LEV) Test Protocol by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health.

Volumetric airflow (Q) in CFM of an LEV is determined by: $Q = V \times A$

Where: V = Average air velocity at hood's face, point of measurement (ft/min)
A = Area of Hood's face monitored ($ft^2$)

It is required by NIH testing protocols that the calculated velocity at the point of work is 50 ft/min (minimum).

Capture velocity is the calculated air velocity required at the point of steam release and necessary for receiving potentially contaminated air into the hood. This is not a measured value. Capture velocity can be calculated by:

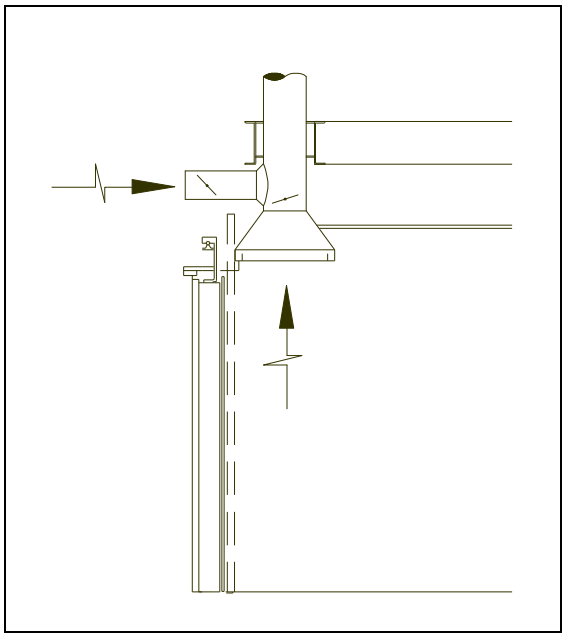
$$V' = Q / 1.4\ PD$$

Where: Q = Volumetric airflow through hood ($ft^3$/min.)
K = A constant, varying with dimensional relations of canopy and source of contaminant [A value of 1.4 has been established where horizontal dimensions of the canopy are 40% greater than the corresponding dimensions of the source.]
P = Perimeter of work area, or perimeter of source (ft.)
D = Vertical distance between source (top of autoclave door) and canopy (ft.)
V'= required average air velocity through area between source and canopy (fpm).

In the setting of a canopy hood located above an autoclave or sterilizer door, the "work area" is defined as the vertical planar surface exposed when the sterilizer door is opened. For the purposes of calculation, parameter D will be taken as the height between the top of the sterilizer door and the capture area of the hood. The site of contaminant generation is the top of the door as defined by NIH for this protocol. Per NIH instruction, parameter P will be taken as that sterilizer door width and a horizontal extension (width of hood's face) to form a rectangle or square.

Current building design calls for installation of all canopy hoods at 2440 mm above finished floor. Recent discussions with ORFDO have indicated this height can be reduced to 1980 mm. There will therefore be sufficient headroom for standing immediately in front of the autoclave when it is not in use.

A Crucial Note: A deep skirt around the edges of a canopy used over autoclaves is recommended. The thermal head or stack effect can cause some spillage around the edges of the canopy if there is not sufficient skirt depth for effective containment, during the exhaust transition to the duct. {See following pages for example of canopy currently in use over an autoclave}.



Placement of canopy directly over rising steam is essential for 100% receiving effectiveness.

Example of Calculations for above Canopy:

With current hood flow, the capture velocity is:

Q = VA

V = 301 avg. (fpm)

A = 5.25 ft. squared

Q = 1580.25 CFM

V'= Q / 1.4 PD

V' = 1580.25 CFM / 1.4(6.42ft x 1.75ft)

V' = 100.47 ft/min., > 50 ft/min minimum

A minimal hood flow, with a face velocity of 149.8 fpm, will deliver a capture velocity of 50 ft/min. Because of the hood's design with a deep skirt, its effective accommodation and containment capacity is maintained.

E.6 Selecting and Specify Variable Frequency Drives for HVAC Systems by Farhad Memarzadeh, Ph.D., P.E., of the National Institutes of Health.

ABSTRACT

Increasing energy costs over the past decade have given rise to the use of Variable-Speed Drives (VFD's) in efforts to reduce energy costs. The reliability of these drives has greatly improved over the first generations' and, as sales have increased, the cost has dropped to a point where these drives are very cost effective, if properly applied.

For variable-speed drives to be considered for a HVAC application, certain basic requirements will increase there effectiveness. HVAC systems that generally benefit from VFD's include air handling systems that can afford a turn down of at least 20% due to the load variation in the space that are serving, secondary pumping for chilled-water systems, hot-water pumps, and most other pumping systems with variable-flow requirements. VFD's generally are not effective for primary chilled-water or other pumping systems where constant flow is desired.

This article describes in detail different types of VFD's and addresses specific issues regarding the usage and specification of VFD's.

TYPES of VARIABLE FREQUENCY DRIVES

Variable frequency drives (VFD's), a type of variable speed drive, are motor controllers that vary the speed of squirrel cage induction motors. VFDs save substantial energy when applied to variable-torque loads, and result in reductions in electricity bills in most facilities. These energy savings are possible with variable-torque loads, such as fans and pumps, because torque varies as the square of speed, and horsepower varies as the cube of speed. For example, if fan speed is reduced by 20%, motor horsepower (and energy consumption) is reduced by 50%. VFD's generate variable voltage and frequency output in the proper volts/hertz ratio for the motors from the fixed utility-supplied power. VFD's can be retrofitted into existing motor systems, and can operate both standard and high-efficiency motors ranging in size from 1/3 HP to several thousand HP. Unlike mechanical or hydraulic motor controllers, they can be located remotely and do not require mechanical coupling between the motor and the load. This simplifies installation and alignment of motor systems.
Variable-flow applications where throttling or bypass devices are used to modulate flow are good candidates for VFD's. These include centrifugal fans, pumps (centrifugal, propeller, turbine), agitators, and axial compressors. If HVAC fans have inlet vanes or outlet dampers to throttle full air output installed in variable-air-volume systems, these dampers or vanes typically can be removed or disabled and retrofitted with VFD's. Circulation pumps for chilled water often have throttling or bypass valves that can be retrofitted with VFD's.

Three major VFD designs are commonly used: pulse width modulation (PWM), current source inverter (CSI), and variable voltage inverter (VVI). A fourth type, the flux vector PWM drive, is gaining popularity but is considered too expensive and sophisticated for normal applications. Knowing the characteristics of the load is critical for evaluating the advantages and disadvantages of each available technology.

[1] Pulse width modulation (PWM) is the dominant VFD design in the 1/2 HP to 500 HP range because of its reliability, affordability and availability. PWM outputs emulate sinusoidal power waves by varying the width of pulses in each half cycle. Advantages of PWM's are low harmonic motor heating, excellent input displacement power factor, high efficiencies at 92% to 96%, and ability to control multiple motor systems with a single drive.

[2] Current source inverter (CSI) designs are quite reliable due to their inherent current-limiting characteristics and simple circuitry. CSI's have regenerative power capabilities, meaning that CSI drives can reverse the power flow back from the motor through the drive. However, CSI's "reflect" large amounts of power harmonics back to the source, have poor input power factors, and produce jerky motor operations (cogging) at very low speeds. CSI's are typically used for large (over 300 HP) induction and synchronous motors.

[3] Voltage source inverter (VSI) designs are similar to CSI designs, but VSI's generate variable-frequency outputs to motors by regulating voltage rather than current. Harmonics, power factor, and cogging at low frequencies can be problems.

The best applications for VFD's are large motors that can operate for many hours each year at reduced speeds. Some opportunities common in facilities include the following:

[1] Variable-air-volume HVAC fans. Air flow in older VAV systems is usually controlled by opening and closing dampers or inlet vanes. Because the systems often operate at low air flow, large energy savings are possible by conversion to VFD's. VFD's vary motor speed in order to match fan output to varying HVAC loads.

[2] Cooling tower fans. Cooling towers may be good candidates for VFD's because motors are large, fans can operate for long periods of time, and loads can vary both seasonally and diurnally.

[3] Circulating water pumps for chillers and boilers. Pumping systems can be made variable by sequencing fixed-speed pumps and a single variable speed pump. This will save the cost of installing VFD's on each pump.

[4] Special industrial applications such as grinding and materials handling where precise speed control is required. The economics depend on the size and run-time of the motors involved.

VFD's should be properly specified and installed to avoid generation of excessive electrical noise and harmonics as well as damage to their electronics. This includes proper grounding, mounting, connection, voltage, and cooling. The specification of the VFD's should as the minimum include the following:

1. What level of reliability is required of the VFD system?

2. What operational overloads and starting conditions are required by the application?
   Typical requirements may be: Variable torque = 115% for 1 minute, Constant torque = 150% for 1 minute

3. How will control commands for the VFD be generated by the process?
   - Manual / potentiometer
   - Analog current loop 4-20 mA
   - Serial communication (RS232, RS485, etc.)
   - Isolated or non-isolated
   - Process feedback (pressure, temperature, flow, etc.)

4. What characteristic surges, sags or momentary discontinuities are present in the supply? Are there any other non-linear loads on the feeder?
   - KVA, Short circuit level
   - Power factor capacitors
   - Breaker reclosing
   - Lightning

5. What levels of voltage distortion exist on the power system before the VFD is applied? What harmonic current spectrum will be injected into the supply system by the VFD? What is the magnitude of distortion on the supply voltage before and after? Will this harmonic current injection affect other loads?

6. What speed range is required? Will the load be operated beyond base speed?

7. Are all parts of the rotating load suitable for the range of vibration excitation frequencies?

8. What waveform does the VFD produce? Are there any constraints on motor connection length?

9. Is the motor sized to provide necessary load torque while operating at reduced speed? The power capability of the motor may be restricted at low speeds. Compare the motor output capability with the load requirement. An additional cooling fan may be required for constant torque loads. (This pertains to constant torque systems, such as compressors, etc.)

10. What heat rejection occurs in the VFD controller? How are the losses removed from the equipment? The heat generated within the VFD is normally removed by air or water cooling.

11. What is the range of voltage and frequency of the electric supply which will permit full rated output of the VFD? What happens outside the range? What line transients can be tolerated? What is the VFD input power factor?

12. How does the VFD operate under fault conditions? For example, mechanical overload, electrical short circuit in the motor circuit or a ground fault in the load system.

13. What motor protection is provided by the VFD equipment? What additional protection is advised for comprehensive system protection, e.g., overload, overspeed, reverse rotation.

14. What information is available from the manufacture for system operations and maintenance? What self diagnostic tools are included or available? Warranty offered? Training available? Operation and maintenance manuals?

15. Total Power Factor (i.e., Real P.F. and Apparent P.F.). The difference between the two is caused by inductance (reactive element) in transformers, motors, etc.

16. Harmonic Voltages and Currents

Variable Frequency Drives (VFD's) inject harmonic currents into the power system due to the nonlinear nature of switching in electronic power devices. The harmonic currents combined with the system impedance frequency response characteristic and create harmonic voltage distortion. The harmonic voltages and currents can cause spurious operation of PEPCO and NIH relays and controls, capacitor failures, motor and transformer overheating, and increased power system losses. These problems are usually compounded by the application of power factor correction capacitors (especially on the NIH's low-voltage system), which can create resonance conditions that magnify the harmonic distortion levels. Several concerns associated with harmonic distortion levels need to be addressed in the specification. This will avoid significant harmonic-related problems with both the VFD equipment and the NIH operations controlled. These concerns include the following:

Harmonic distortion on both the supply side and motor side of the drive.
Equipment derating due to harmonic distortion produced by VFDs.
Audible noise caused by high-frequency (several kilohertz) components in the current and voltage.
Harmonic filter design and specification.

17. Nuisance Tripping Concerns

A three-phase VFD system consists of three basic components (rectifier, dc link, and inverter) and a control system. The rectifier converts the three-phase 60-Hz ac input to a dc signal. Depending on the system, an inductor, a capacitor, or a combination of these components smoothes the dc signal (reduces voltage ripple) in the dc link. The inverter circuit converts the dc signal into a variable-frequency ac voltage to control the speed of the induction motor. Since for this application a Voltage-Source Inverter (VSI) Drive is considered, I will outline the concerns regarding this particular device. These drives (the most common types up to 300 hp) use a large capacitor in the dc link to provide a relatively consistent dc voltage to the inverter. The inverter then chops this dc voltage to provide a variable-frequency ac voltage for the motor. VSI drives can be purchased off the shelf and employ pulse-width-modulation (PWM) techniques to improve the quality of the output voltage waveform. However, here is a concern regarding nuisance tripping due to capacitor switching transients. Small VFD's have a VSI rectifier (ac to dc) and use as PWM inverter (dc to ac) to supply the motor. This design requires a dc capacitor to smooth the dc link voltage. The controls for this type of drive have protection for dc overvoltages and under voltages with narrow thresholds. It is not uncommon for the dc over voltage control to cause tripping of the drive whenever the dc voltage exceeds 1.17 per unit (for this particular application 760 volts for a 480-volt application). Since the dc capacitor is connected alternately across each of the three phased, drives of this type can be extremely sensitive to overvoltages on the ac power side. One event of particular concern is capacitor switching on the PEPCO system. PEPCO voltage switching transients result in a surge of current into the dc link capacitor at a relatively low frequency (300-800 Hz). This current surge charges the dc link capacitor, causing an over voltage to occur (through Ohm's law). The over voltage (not necessarily magnified) exceeds the voltage tolerance thresholds associated with the over voltage protection, which most likely will trip the VFD out of service. This is called nuisance tripping because the situation can occur day after day, often at the same time. Several methods are available to ameliorate such tripping; some are simple and some costly. Use of a harmonic filter to reduce overvoltages, an expensive alternative, is effective in protecting drives from component failure, but may not completely eliminate nuisance tripping of small drives. The most effective (and inexpensive) way to eliminate nuisance tripping of small drives is to isolate them from the power system with series inductor (chokes). With a concomitant voltage drop across the inductor, the series inductance of the choke(s) reduce(s) the current surge into the VFD, thereby limiting the dc over voltage. The most important issue regarding this method is that the designer should determine the precise inductor size for each particular VFD; this requires a detailed transient simulation that takes into

account capacitor size, transformer size, etc. The choke size must be selected carefully. If the choke has too much impedance, it can increase harmonic distortion levels and notching transients at the drive terminals. Chokes for this application are commercially available in sizes from 1.5% to 5% of the VFD impedance at various hp ratings. A size of 3% is sufficient to avoid nuisance tripping due to capacitor switching operations. Standard isolation transformers serve the same purpose.

18. Voltage Sag Concerns

Despite the many advantages provided by VFDs, the concern for nuisance tripping during voltage sag conditions remains. This power quality concern involves the control sensitivity to short-duration voltage sags and momentary interruptions. Actually, many different kinds of controls, and even motor contractors, are sensitive to these voltage sags. Therefore, voltage sags caused by faults on the power system represent one of the most important problems that can be experienced by the NIH with sensitive loads. Whenever there is a fault on the transmission or distribution system serving the NIH facility (faults cannot be completely avoided regardless of the system design), there will be either a voltage sag or an interruption. If the fault occurs on a parallel distribution feeder circuit or on the transmission system, there will be a voltage sag that lasts until the fault is cleared by some protective device (typically 3-30 cycles depending on the fault location). A method of predicting the likelihood of faults in a certain region along with knowledge of equipment sensitivity can be used to determine an "area of vulnerability." A combination of computer short-circuit simulations and lightning performance analysis should be used to determine the affected area. The VFD controls should be designed to handle these voltage sag conditions without tripping. I have not seen in the specifications a ride-thru capability. This is an important consideration when VFDs are applied in critical processes such as NIH, where nuisance tripping can cause significant problems. The designer should evaluate the level of sensitivity of the controls to voltage sags. If such concern exists we should consider applying power conditioning to the controls themselves. Ferroresonant transformers can handle voltage sags down to approximately 60% of the nominal voltage. This is sufficient to handle virtually all voltage sags caused by single line-to-ground faults on the power system. If additional protection is needed, the controls can be protected with an uninterruptible power supply (UPS) system, which can handle complete interruptions in the input signal.

19. Transient Over voltage Concerns

Transient overvoltages occur in connection with capacitor switching. Each time a capacitor is energized, a transient voltage oscillation occurs between the capacitor and power system inductance. The result is a transient over voltage that can be as high as 2.0 per unit (of the normal voltage) at the capacitor location. The magnitude is usually less than 2.0 per unit due to dampening provided by system loads and losses. The transient overvoltages caused by capacitor energizing are generally not a concern to PEPCO because their magnitude is usually below the level at which surge protective devices operate (1.5-2.0 per unit). However, these transients can be magnified at the NIH facility if the NIH has low-voltage capacitor banks for (displacement) power factor correction. ( The designer should check for this matter.) When the frequency of a transient over voltage matches the series-resonant frequency of the NIH's transformer coupled with the PEPCO'S capacitor(s) at the East Substation, a low-impedance, high-current (at the resonant frequency) condition results. As this large current passes through the NIH transformer it induces a large voltage "drop" that passes through zero voltage to create a large voltage of opposite sign (because of a phase-angle change) at the resonant frequency. The VFD and the NIH paralleled capacitor (and their surge protection devices) then see this magnified voltage (compared to distribution feeder voltage). When the resonant-frequency current completes its path to ground through the capacitor, the voltage experiences a "boost" to the ground-reference voltage. The magnification of capacitor switching transients is most severe when the following conditions exist: The capacitor switched on the higher voltage system is much larger (kVAR) than the capacitor at the low-voltage bus. Generally, this situation occurs most frequently for substation switching. The frequency of oscillation that occurs when the high-voltage capacitor is energized is close to the resonant frequency formed by the step-down transformer in series with the low-voltage capacitor. There is little resistive load on the low-voltage system to provide dampening of the transient, as is usually the case for industrial plants (motors do not provide significant damping of these transients). It is not uncommon for magnified transients at low-voltage capacitors to range from 3.0-4.0 per unit. These transients have significant energy associated with them and are likely to cause failure of protective devices, metal oxide varistors (MOV's), electronic components (silicon-controlled rectifiers, etc.), and capacitors. VFD's are particularly susceptible

to these transients because of the relatively low peak-inverse voltage ratings of the semiconductor switches and the low-energy ratings of the MOV's used to protect the VFD power electronics. The following should be evaluated and identified in the specifications to control these magnified transient overvoltages: By using vacuum switches with synchronous closing control to energize the capacitor bank and control the capacitor switching transient. By providing high-energy MOV protection on the 480-volt buses. (The energy capability of these arresters should be at least 1 kJ.) By using tuned filters for power factor correction instead of just shunt capacitor banks. (The tuned filters change the frequency response of the circuit and usually prevent magnification problems. This solution combines power factor correction, harmonic control, and transient control.)

20. EMI and RFI Concerns

IEEE Std. 519, Recommended Practices And Requirements for Harmonic Control In Electric Power Systems, recommends limits for voltage distortion and harmonic current resulting from non-linear loads. However, the IEEE standard is not intended to cover the effects of radio frequency interference. As a result, specifications will occasionally refer to FCC Rules & Regulations volume 2 Part 15 Subpart J Class A (referred to as "FCC rule") to establish limits on electromagnetic emission for VFD's. The "FCC rule" was printed in October 1982 primarily for computing devices. Computers will generate RF energy and possibly cause interference with nearby equipment if misapplied. Generally, the rule sets conducted and radiation RF limits for electronic devices using timing signals or digital techniques with pulse rates in excess of 10,000 pulses per second. Technically speaking, VFD's with high frequency timing circuits conform to this description, although they are not intended as a computing device described in the "FCC rule." The primary and more significant source of EMI from a VFD stems from the power circuits, and in this respect, drives become an incidental radiation device. The only requirement for incidental radiation devices in the "FCC rule" is that they shall be operated so that the RF energy emitted does not cause harmful interference - if so, the operator must eliminate the interference. All VFD's, regardless of the manufacturer, will produce electromagnetic emissions to some degree. Primarily, these emissions are due to the steep wave fronts and very rapid switching of power semi-conductors in the VFD. Typically this occurs when transistors, GTO's or other "fast devices" are gated on and off in dc chopper circuits, and inverter power circuits for PWM, current source, and six-step drives. Typically conductors to the VFD's and motor act as an antenna, and radiate the RF energy into the media. Therefore it is possible for RF to be induced into nearby antennas and other conductors, and be carried to the loads in that circuit. Holding a portable AM radio near a power outlet in close proximity to an EMI source can be evidence of this situation. DDC control system, telecommunication services and other electronic equipment utilizing very high frequencies may experience noisy interference or malfunctions when subject to EM/RF energy. The specification should clearly outline the corrective measures required. The first and foremost corrective measure to avoid problems associated with EMI is proper routing of the drive conductors in separate metallic conduits, and even separate raceways, if practical, and as remote as possible from any other conductors or suspect equipment. Usually, this will be sufficient to avoid EMI problems. EM/RF filters can be engineered for a system to trap or inhibit high frequency emissions into power system conductors. However, due to the nature of EMI the effectiveness of any filter is highly sensitive to where it is installed. Further, it is not assured that the filter will correct the problem even though it may meet FCC limits. Most manufacturers will include this footnote with their literature. "Filters are expensive and usually require additional space. It is recommended that they be furnished only when they are specifically required to avoid or solve a problem after exhausting all proper installation methods. In addition, filters are an additional component and must be considered in the overall reliability of a power system." To contain RF radiation through the media from VFD, complete shielding using a metallic enclosure is required. This will usually contain most of the radiated RF to a reasonable distance.

21. Ensure that the power voltage supplied to VFD's is stable within plus or minus 10% to prevent tripping faults.

22. Motors operating at low speeds can suffer from reduced cooling. For maximum motor protection on motors to be run at low speeds, install thermal sensors that interlock with the VFD control circuit. Standard motor protection responds only to over-current conditions.

23. Speed control wiring, which is often 4 mA to 20mA or 0 VDC to 5 VDC, should be separated from other wiring to avoid erratic behavior. Parallel runs of 115V and 24V control wiring may cause problems.

*Precautions* for specifying, installing and operating VFDs are numerous. Improper installation and start-up accounts for 50% of VFD failures.

1. Use the VFD start-up sheet to guide the initialization check prior to energizing the VFD for the first time.

2. Corrosive environments, humidity above 95%, ambient air temperatures exceeding 40°C (104°F), and conditions where condensation occurs may damage VFDs.

3. If a VFD is started when the load is already spinning, the VFD will try to pull the motor down to a low, soft-start frequency. This can result in high current and a trip unless special VFDs are used.

4. Switching from grid power to emergency power while the VFD is running is not possible with most types of VFDs. If power switching is anticipated, include this capability in the specification.

5. If electrical disconnects are located between the VFD and motor, interlock the run-permissive circuit to the disconnect.

6. If a motor always operates at rated load, a VFD will increase power use, due to electrical losses in the VFD.

7. Use "inverter duty" motors on new installations that will have VFDs.

## References

Murphy, Howard G., "Power Quality Issues with Adjustable Frequency Drive - Coping with Power Loss and Voltage Transients," *Iron and Steel Engineer*, February 1994.

Turkel, Solomon S., "Understanding Variable Speed Drives (parts 1 to 6)," *Electrical Construction and Maintenance*, February to July 1995.

# Appendix F

## Links to References on the World Wide Web

## F.1 Links to References on the World Wide Web

Where abbreviations and acronyms are used in the NIH DRM, they shall mean the recognized name of the entities in the following list. This list is not meant to be all-inclusive. Names and Web site addresses are subject to change and are believed to be accurate and up to date as of the date of this release of the NIH DRM.

| Abbreviation | Title of Standard or Regulatory Organization and Web Site |
|---|---|
| ADAAG | Americans with Disabilities Act Accessibility Guidelines<br>Available from the U.S. Access Board<br>www.access-board.gov |
| CFR | Code of Federal Regulations<br>Available from the Government Printing Office<br>www.access.gpo.gov/nara/cfr/index.html |
| UFAS | Uniform Federal Accessibility Standards<br>Available from the U.S. Access Board<br>www.access-board.gov |
| BMBL | CDC/NIH *Biosafety in Microbiological and Biomedical Laboratories*<br>Available in hard copy from the U.S. Government Printing Office or online from the Centers for Disease Control and Prevention<br>www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm |
| Guide | Guide for the Care and Use of Laboratory Animals<br>Available from the National Academies Press<br>www.nap.edu/catalog/5140.html |

## F.2 Links to Industry Associations

| Abbreviation | Title of Organization or Industry Association and Web Site |
|---|---|
| AA | Aluminum Association, Inc. (The)<br>http://www.aluminum.org/ |
| AABC | Associated Air Balance Council<br>http://www.aabchq.com/ |
| AAMA | American Architectural Manufacturers Association<br>http://www.aamanet.org/ |
| ACGIH | American Conference of Governmental Industrial Hygienists<br>www.acgih.org |
| ACI | American Concrete Institute/ACI International<br>http://www.aci-int.org/ |
| ACPA | American Concrete Pipe Association<br>http://www.concrete-pipe.org/ |

| Abbreviation | Title of Organization or Industry Association and Web Site |
|---|---|
| AEIC | Association of Edison Illuminating Companies, Inc. (The)<br>http://www.aeic.org/ |
| AFPA | American Forest & Paper Association<br>(See AF&PA.) |
| AF&PA | American Forest & Paper Association<br>http://www.afandpa.org/ |
| AGA | American Gas Association<br>http://www.aga.org/ |
| AHA | American Hospital Association<br>http://www.aha.org/ |
| AIA | American Institute of Architects (The)<br>www.aia.org |
| AISC | American Institute of Steel Construction<br>www.aisc.org |
| AITC | American Institute of Timber Construction<br>www.aitc-glulam.org |
| AMCA | Air Movement and Control Association International, Inc.<br>www.amca.org |
| ANSI | American National Standards Institute<br>www.ansi.org |
| APA | Architectural Precast Association<br>www.archprecast.org |
| API | American Petroleum Institute<br>www.api.org |
| ARI | Air-Conditioning & Refrigeration Institute<br>www.ari.org |
| ASCE | American Society of Civil Engineers<br>www.asce.org |
| ASHE | American Society of Healthcare Engineering<br>www.ashe.org |
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers<br>www.ashrae.org |
| ASME | ASME International (The American Society of Mechanical Engineers International)<br>www.asme.org |
| ASPE | American Society of Plumbing Engineers<br>www.aspe.org |
| ASSE | American Society of Sanitary Engineering<br>www.asse-plumbing.org |
| ASTM | ASTM International (American Society for Testing and Materials International)<br>www.astm.org |

| Abbreviation | Title of Organization or Industry Association and Web Site |
|---|---|
| AWI | Architectural Woodwork Institute<br>www.awinet.org |
| AWS | American Welding Society<br>www.aws.org |
| AWWA | American Water Works Association<br>www.awwa.org |
| BIA | Brick Industry Association (The)<br>www.bia.org |
| BSI | Building Stone Institute<br>www.buildingstone.org |
| CBMA | Certified Ballast Manufacturers Association<br>www.certbal.org |
| CRSI | Concrete Reinforcing Steel Institute<br>www.crsi.org |
| EIA | Electronic Industries Alliance<br>www.eia.org |
| FM | Factory Mutual System<br>(See FMG.) |
| FMG | FM Global (Formerly: FM - Factory Mutual System)<br>www.fmglobal.com |
| ICEA | Insulated Cable Engineers Association, Inc.<br>www.icea.net |
| IEC | International Electrotechnical Commission<br>www.iec.ch |
| IEEE | Institute of Electrical and Electronics Engineers, Inc. (The)<br>www.ieee.org |
| IESNA | Illuminating Engineering Society of North America<br>www.iesna.org |
| ILI | Indiana Limestone Institute of America, Inc.<br>www.iliai.com |
| ISEA | International Safety Equipment Association<br>www.safetyequipment.org |
| LEED | Leadership in Energy and Environmental Design<br>Available from the US Green Building Council<br>http://www.usgbc.org/ |
| LPI | Lightning Protection Institute<br>www.lightning.org |
| MIA | Marble Institute of America<br>www.marble-institute.com |
| NAAMM | National Association of Architectural Metal Manufacturers<br>www.naamm.org |

| Abbreviation | Title of Organization or Industry Association and Web Site |
|---|---|
| NBBI | National Board of Boiler and Pressure Vessel Inspectors<br>www.nationalboard.org |
| NBGQA | National Building Granite Quarries Association, Inc.<br>www.nbgqa.com |
| NCMA | National Concrete Masonry Association<br>www.ncma.org |
| NCPI | National Clay Pipe Institute<br>www.ncpi.org |
| NCTA | National Cable & Telecommunications Association<br>www.ncta.com |
| NEBB | National Environmental Balancing Bureau<br>www.nebb.org |
| NECA | National Electrical Contractors Association<br>www.necanet.org |
| NEMA | National Electrical Manufacturers Association<br>www.nema.org |
| NETA | International Electrical Testing Association<br>www.netaworld.org |
| NFPA | National Fire Protection Association<br>www.nfpa.org |
| NFRC | National Fenestration Rating Council<br>www.nfrc.org |
| NPCA | National Precast Concrete Association<br>www.precast.org |
| NRCA | National Roofing Contractors Association<br>www.nrca.net |
| NSF | NSF International (National Sanitation Foundation International)<br>www.nsf.org |
| PCA | Portland Cement Association<br>www.portcement.org |
| PCI | Precast/Prestressed Concrete Institute<br>www.pci.org |
| PDI | Plumbing & Drainage Institute<br>www.pdionline.org |
| SEFA | Scientific Equipment and Furniture Association<br>www.sefalabfurn.com |
| SMACNA | Sheet Metal and Air Conditioning Contractors' National Association<br>www.smacna.org |
| SWI | Steel Window Institute<br>www.steelwindows.com |

| Abbreviation | Title of Organization or Industry Association and Web Site |
|---|---|
| TIA/EIA | Telecommunications Industry Association/Electronic Industries Alliance<br>www.tiaonline.org |
| UL | Underwriters Laboratories Inc.<br>www.ul.com |
| WWPA | Western Wood Products Association<br>www.wwpa.org |

## F.3 Links to Code Agencies

| Abbreviation | Title of Code Organization and Web Site |
|---|---|
| BOCA | BOCA International, Inc.<br>www.bocai.org |
| ICBO | International Conference of Building Officials<br>www.icbo.org |
| ICC | International Code Council, Inc.<br>(Formerly: CABO - Council of American Building Officials)<br>www.intlcode.org |

## F.4 Links to Federal, State, and Local Agencies

| Abbreviation | Title of Federal Agency and Web Site |
|---|---|
| EPA | Environmental Protection Agency<br>www.epa.gov |
| FCC | Federal Communications Commission<br>www.fcc.gov |
| FDA | Food and Drug Administration<br>www.fda.gov |
| GSA | General Services Administration<br>www.gsa.gov |
| DHHS | Department of Health and Human Services<br>www.dhhs.gov |
| MCDOT | Montgomery County, MD, Department of Transportation<br>Standard Details for Roadways<br>www.montgomerycountymd.gov/mc/services/permiting |
| MDE | Maryland Department of the Environment<br>http://mde.state.md.us |
| MDOT | Maryland Department of Transportation<br>State Highway Administrator<br>Standard Details for Installation of Storm Drains<br>www.sha.state.md.us/dm_s_p.htm |

| Abbreviation | Title of Federal Agency and Web Site |
|---|---|
| NIBS | National Institute of Building Sciences<br>www.nibs.org |
| NIST | National Institute of Standards and Technology<br>www.nist.gov |
| OSHA | Occupational Safety and Health Administration<br>www.osha.gov |
| PBS | Public Building Service<br>(See GSA.) |
| PEPCO | Potomac Electric Power Company<br>www.pepco.com |
| USPS | Postal Service<br>www.usps.com |
| WSSC | Washington Suburban Sanitary Commission<br>http://www.wssc.dst.md.us/index.cfm |

## F.5 Links to Miscellaneous Publications and References

| Title of Publications, References, and Web Site |
|---|
| Air Force Handbook (I) 32-1163; *Engineering Weather Data*<br>www.afcesa.af.mil/Directorate/CES/Mechanical/Energy/Weather%20Handbook/AFH(I)%2032-1163Draft.pdf |
| *Building Code Requirements for Reinforced Concrete*<br>www.concrete.org/bookstore/bkstr.htm |
| Center for Universal Design<br>www.design.ncsu.edu/cud/ |
| College of American Pathologists<br>www.cap.org |
| Energy Star Products<br>www.energystar.gov |
| *Minimum Design Loads for Buildings and Other Structures - ASCE 7*<br>www.pubs.asce.org |
| Whole Building Design Guide<br>www.wbdg.org |

# Appendix G

**Lease Facilities Checklist**

# Lease Facilities Design Requirements Manual Checklist

The NIH Design Requirements Manual (DRM) establishes policy, design standards, and technical criteria for use in programming, designing, and constructing new buildings, and major and minor alterations for the NIH. This document applies to the design and construction for all NIH facilities nationwide, including those that are owned by the NIH and those that are leased by the Federal Government for use by the NIH. NIH grantees should refer to their Grants Officer for application of the DRM to specific construction grants.

Facility acquisitions include the purchase and/or lease of existing structures or facilities by the Federal Government. Existing facilities that are purchased and/or leased for use by NIH employees or which will house NIH equipment shall comply with all applicable Federal, National, State/local, and Departmental and Agency regulations and policies, including the DRM

It is imperative that facilities acquired by lease for the NIH are capable of meeting all safety criteria and all other criteria that in any way will have an adverse effect on the health and/or safety of the building occupants or have an adverse affect on the integrity of ongoing research.

It is strongly advised that any proposed existing facility be evaluated prior to entering into a purchase or lease agreement for its capability to comply with the DRM.

Purchased or leased facilities whose intended function will be to conduct biomedical research shall be evaluated for their ability to provide flexible, adaptable, and expandable space to the greatest extent possible. The extent to which the facility will adhere to the requirements outlined in the DRM should be reviewed by the NIH on a case-by-case basis. Elements such as the length of the lease term and future plans/programs of the occupants of the building should be considered in the review. Variances from the NIH DRM requirements shall be sought during the design process.

## Purpose

To apply the DRM and the waiver checklist to leased facility projects.

## Scope or Content

The procedure contains a checklist for each major design discipline to use in applying the DRM to leased facilities. For security requirements only, instead of a waiver checklist, a separate guideline was written for lease facilities. The DRM comply with the ISC Security

Standards for Leased Space which where developed to provide a distinct set of standards specifically for leased locations mandated by HHS.

## Responsibilities

The contracting officer is responsible for verifying that the lease requires incorporation of the DRM and Lease Facility Checklist into all design and construction in the facility. The PO is responsible for verification that this is done. The PO may delegate all or part of the work to others on the project team.

## Procedures

During the programming phase of each lease facility design and construction project, a representative of each design discipline on the project team shall review the DRM and the Leased Facility Checklist and note how and where it applies to the project. Note that instead of a checklist, a separate guideline was written for lease facilities security requirements.

Note that the Lease Facilities Checklist includes only those items that are waived. Every part of the DRM not listed in the “Guide Reference” column on the table applies to all NIH projects.

Where the table shows an "x" in the "all" column, the referenced paragraph is waived for any lease project regardless of the lease duration as described in the "description column". For example, in the architectural sheet, for DRM reference, lease facilities in existing buildings are not required to conform to the thermal performance of windows, exterior doors, glazed panels and skylights. Because the description states existing facilities, new facilities would need to conform unless a variance is approved. Existing facilities would not need a variance when in non-conformance. In some cases the description summarizes or copies the part that is waived.

For lines in the checklist where the "x" is in the "<=5" column, then the application is similar to that described above except that instead of waiving the requirement for all lease projects, these are only waived as described for leases that are 5 years or less. Likewise the "<=10" column are for waivers that only apply to leases with a 10 or less year duration.

The Quality Assurance Plan on each lease facility design and construction project shall include verification that the requirements of the DRM and checklist have been met. A team that has experience with NIH lease facility projects may elect to only check once during the design. A team that hasn’t done NIH work should have a more in depth plan.

# NIH DRM LEASED FACILITY WAIVER CHECKLIST
# ARCHITECTURAL

Instructions for use: The below checklist includes only those items that are waived. Every part of the NIH DRM not listed in the “Guide Reference” column on the table applies to all NIH projects. Where the table shows an "x" in the "all" column, the referenced paragraph is waived for any lease project regardless of the lease duration as described in the "description column". For example, in the architectural sheet, for DRM reference, lease facilities in existing buildings are not required to conform to the thermal performance of windows, exterior doors, glazed panels and skylights. Because the description states existing facilities, new facilities would need to conform unless a variance is approved. Existing facilities would not need a variance when in nonconformance. In some cases the description summarizes or copies the part that is waived. For lines in the checklist where the "x" is in the "<=5" column, then the application is similar to that described above except that instead of waiving the requirement for all lease projects, these are only waived as described for leases that are 5 years or less. Likewise the "<=10" column are for waivers that only apply to leases with a 10 or less year duration.

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | 4-2-10-C | Thermal Performance of Windows, Exterior Doors, Glazed Panels and Skylights - These performance standards are for new construction, existing facilities would not be able to comply. |
| | | | X | 4-2-00-B | Operable Windows - Operable windows are not allowed in laboratory building and animal facilities. |
| | | | X | 4-2-10-C.2 | Glazing - These performance standards are for new construction, existing facilities would not be able to comply. |
| | | | X | 4.3-10-B.1 | Drywall Partitions - The DRM requires 20 gauge, 3 5/8" s metal studs for wall construction. 25 gauge studs for wall construction are acceptable for office applications only. |
| | | | X | 4-4 | Finishes and Materials - Selection of finishes, materials, furniture and products are required to made from the GSA Federal Supply Schedule. (office only) |
| | | | X | 4-4-00-A<br>4-4-10-A.1 | Lay-in Ceiling Tile - Standard calls for all ceiling tiles to be NIH standard, many leased facilities have their own “standards.” Changing may not be cost effective. |
| | | | X | 4-4-10-E | Window Treatments - Standard calls for use of draperies and blinds, using neutral colors as a standard, many leased facilities have their own “standards.” Changing may not be cost effective. |
| | | | X | NIH Interior Signage Manual | Signage - Standard calls for complying with the NIH Interior Signage Users Manual, many leased facilities have their own “standards.” Also it calls for all interior and exterior signage to comply with ADAAG. Changing may not be cost effective and if we were only leasing a portion of a facility, it would not be practical. |
| | | | X | Chapter 2 | Circulation Into and Within Buildings from Loading Dock - Standard calls for elevator lobbies and corridors adjacent to the loading dock : passageways in this area to have dual-level protective bumpers, wall, corner and door guards installed. |
| | | | X | 4-3-10-A | Doors - These performance standards are for new construction, existing facilities would not be able to comply. These standards would add a great deal to the cost and would not be practical for a short term lease. This waiver does not apply to animal facilities or fire code requirments. |

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | 4-6-10 | Freight Elevators - The standard calls for the entrance to freight elevators to be from the materials-handling pas-sageway, not from the building lobby - this may not be possible in existing facilities. |
| | | | X | 4-3-10-A.8 | Mortise Locksets and Lockset Trim - These standards are typical for NIH buildings, but are above what is typically installed in most leased spaces. |
| | | | X | 4-2-10-D.2 | Dock Protection |

# NIH DRM LEASED FACILITY WAIVER CHECKLIST CIVIL ENGINEERING

Instructions for use: The below checklist includes only those items that are waived. Every part of the NIH DRM not listed in the “Guide Reference” column on the table applies to all NIH projects. Where the table shows an "x" in the "all" column, the referenced paragraph is waived for any lease project regardless of the lease duration as described in the "description column". For example, in the architectural sheet, for DRM reference, lease facilities in existing buildings are not required to conform to the thermal performance of windows, exterior doors, glazed panels and skylights. Because the description states existing facilities, new facilities would need to conform unless a variance is approved. Existing facilities would not need a variance when in nonconformance. In some cases the description summarizes or copies the part that is waived. For lines in the checklist where the "x" is in the "<=5" column, then the application is similar to that described above except that instead of waiving the requirement for all lease projects, these are only waived as described for leases that are 5 years or less. Likewise the "<=10" column are for waivers that only apply to leases with a 10 or less year duration.

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | | Metric Standards – is not required for lease space |
| | | | X | 3-3-10-A | Parking Lot Paving Materials |
| | | | X | 3-3-10-B | Materials for Sidewalks, Curbs, Gutters |
| | | | X | 3-3-10-C | Loading Dock Berths - |
| | | | X | 3-3-10-F | Screening; Visual |
| | | | X | 3-1-10-A | Grading |
| | | | X | Section 3-4 | Landscaping |
| | | | X | 3-4-20-A | Tree Types |

# NIH DRM LEASED FACILITY WAIVER CHECKLIST MECHANICAL

Instructions for use: The below checklist includes only those items that are waived. Every part of the NIH DRM not listed in the “Guide Reference” column on the table applies to all NIH projects. Where the table shows an "x" in the "all" column, the referenced paragraph is waived for any lease project regardless of the lease duration as described in the "description column". For example, in the architectural sheet, for DRM

reference, lease facilities in existing buildings are not required to conform to the thermal performance of windows, exterior doors, glazed panels and skylights. Because the description states existing facilities, new facilities would need to conform unless a variance is approved. Existing facilities would not need a variance when in nonconformance. In some cases the description summarizes or copies the part that is waived. For lines in the checklist where the "x" is in the "<=5" column, then the application is similar to that described above except that instead of waiving the requirement for all lease projects, these are only waived as described for leases that are 5 years or less. Likewise the "<=10" column are for waivers that only apply to leases with a 10 or less year duration.

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | | | |
| | X | | | 6-1-00-E. | Redundancy |
| | | | X | 6-1-30-A | For comparison of systems, the life-cycle shall be waived to 15 to 20 years for all lease applications. |
| | | | X | 6-2-00-B | Use of duct lining prohibited |
| | X | | | 6-3-00-E.7 | NIH enhanced system component identification |
| | | | X | | Minimum Pipe Size requirements for Plumbing, HVAC and Fire Protection Systems |
| | | | X | 6-4-00-A | Insulation - Enhanced application requirements for quality |
| | | | X | 6-4-10-A<br>6-4-10-B | Insulation Material Thickness for equipment |
| | | | X | X6-4-A | Material selection, size for piping insulation |
| | | | X | 6-1-00-D.5 | Air Plenums for air distribution not permitted at NIH |
| | | X | | 6-1-00-D.7.d-f | Fume Hood Exhaust Based on the Fume Hood density Policy of the NIH |
| | | X | | 6-1-00-E | Select Supply and Exhaust fan motors one size larger |
| | X | | | 6-1-00-E | Size supply and Exhaust Fans 20% greater air flow for future expansion |
| | | X | | | Size supply and Exhaust branch air ducts for greater of the present air flow or 250 mm minimum duct diameter |
| | | X | | | Thermostatic Traps with no by pass trap lines (Not waived for cage wash, autoclave or other NIH maintained equip-ment.) |
| | X | | | X6-2-B | Hazardous exhaust or special exhaust duct work shall be stainless steel |
| | | | X | 6-2-00-I | Engine Exhaust System- residential and critical mufflers allowed at NIH due to noise concerns. |
| | | | X | 6-3-00-D.1 | PRV stations design criteria and pressure reducing valve selections |
| | | | X | X6-3-E | Trap applications table for heating equipment and piping |
| | | | X | 6-3-00-D.1 | No by pass valve for steam trap, provide dual traps for redundancy |
| | | | X | 6-3-00-C | Leaving water temperature from Chilled Water Plant |
| | | | X | 6-3-00-A.3 | All terminal coils and equipment shall be provided 2-way control valve with 16$^{o}$ C leaving water temp. |
| | | | X | 6-2-00-D | Reverse return piping arrangement for better balancing results (waived for existing building only) |

# NIH DRM LEASED FACILITY WAIVER CHECKLIST PLUMBING

Instructions for use: The below checklist includes only those items that are waived. Every part of the NIH DRM not listed in the “Guide Reference” column on the table applies to all NIH projects. Where the table shows an "x" in the "all" column, the referenced paragraph is waived for any lease project regardless of the lease duration as described in the "description column". For example, in the architectural sheet, for DRM reference D.2.3.1, lease facilities in existing buildings are not required to conform to the thermal performance of windows, exterior doors, glazed panels and skylights. Because the description states existing facilities, new facilities would need to conform unless a variance is approved. Existing facilities would not need a variance when in nonconformance. In some cases the description summarizes or copies the part that is waived. For lines in the checklist where the "x" is in the "<=5" column, then the application is similar to that described above except that instead of waiving the requirement for all lease projects, these are only waived as described for leases that are 5 years or less. Likewise the "<=10" column are for waivers that only apply to leases with a 10 or less year duration.

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | 8-1-30-B.4 | For comparison of systems, the life-cycle shall be waived to 15 to 20 years for all lease applications. |
| | | X | | 8-1-00-A | Modular lay out of piping system |
| | | | X | 8-3-00-A | Each critical facility shall be provided with two separate water services from the campus loop |
| | | | X | 8-1-00-C.2 | Piping arrangement and valving should enable individual shut down of each lab module. |
| | | | X | 8-1-00-C.2 | Double ended horizontal loop sectionalized for alteration and repairs. |
| | | | X | | Up feed of fixtures above is not permitted |
| | | X | | 8-1-00-C.2 | Service run outs at regular intervals and at shafts valve and capped for future expansion and future connections for alterations. |
| | | | X | 8-3-10-A | Water treatment or softeners not required at NIH. |
| | | | X | 8-2-10-E | Separate potable water loop preferred for Emergency eye wash and showers for each floor. |
| | | X | | 8-1-00-C.1 | Domestic potable hot water system heat exchanger is 20% larger than design demand for future expansion. |
| | | X | | 8-3-00-B.3 | Pipe mains shall be sized with 20% greater than calculated design flow |
| | | X | | | Water service main shall not be less than 200 mm in size at NIH. |
| | | | X | 8-1-00-C.2 | Requires double fed horizontal loop with separate risers serving each end for every wing of the building floor. (waived for existing buildings only). |
| | | X | | 8-6 | Lab and Animal Facility waste and vent piping to be acid resistant. Enhanced installation details to ensure quality. (waived for existing buildings only). |
| | | | X | 8-6-00 B.3 | Two way clean out for maintenance access from outside the building. |
| | | | X | X8-7-A | Waste Discharge chart |
| | | X | | 8-8 | Enhanced gas system installation and testing requirements for safety and quality purposes. (waived for existing facilities only.) |

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | X | | X8-8A | Table Vivaria Gas Terminals for Animal Procedures |
| | | X | | 8-8-00-D | Separate system from Lab air with 100% redundancy. |
| | | X | | 8-8-00-D | Enhanced equipment and installation requirements for reliability and quality. |
| | | | X | 8-8-00-D | Air distribution system for modular lab concept with valving and high pressure distribution riser and local pressure reducing station at each floor for flexibility and isolation for maintenance. |
| | | | X | 8-8-00-D | Provide 20% excess capacity allowance for future allowance. |

# NIH DRM LEASED FACILITY WAIVER CHECKLIST FIRE PROTECTION

Instructions for use: The below checklist includes only those items that are waived. Every part of the NIH DRM not listed in the “Guide Reference” column on the table applies to all NIH projects. Where the table shows an "x" in the "all" column, the referenced paragraph is waived for any lease project regardless of the lease duration as described in the "description column". For example, in the architectural sheet, for DRM reference, lease facilities in existing buildings are not required to conform to the thermal performance of windows, exterior doors, glazed panels and skylights. Because the description states existing facilities, new facilities would need to conform unless a variance is approved. Existing facilities would not need a variance when in nonconformance. In some cases the description summarizes or copies the part that is waived. For lines in the checklist where the "x" is in the "<=5" column, then the application is similar to that described above except that instead of waiving the requirement for all lease projects, these are only waived as described for leases that are 5 years or less. Likewise the "<=10" column are for waivers that only apply to leases with a 10 or less year duration.

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE N/A | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | | Local Authority Having Jurisdiction (AHJ) will determine level of conformance on partial renovation projects. |
| | | | X | | Division of Fire Marshal in AHJ only if no local authority exists. |
| | | | X | | Only as required by local AHJ. |
| | | | X | | Dependent upon local AHJ. |
| | | | X | | Automatic extinguishing system can be used instead of 1 hour separation between boiler/furnace room and adjacent space. |
| | | | X | | Reduction of shaft fire ratings in high-rise buildings with use of in-shaft sprinklers is not permitted. |
| | | | X | | Main campus facilities with quantities of hazardous materials in excess of the exempt amounts identified in the IBC “Hazardous Materials” |
| | | | X | | Spray-applied fireproofing shall be cementitious type or a gypsum based product only. |
| | | | X | | Fire and Smoke Dampers (NFPA 90A) Fire |

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE N/A | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | | | Dampers shall be installed in locations where required by the IBC. The IBC requirements shall be modified to allow the omission of fire dampers in 1 hour-or-less fire-rated walls. |
| | | | X | | Smaller modifications, renovations, and alterations (as defined in paragraph J.1.2) shall, whenever feasible, include the provision of capped-off sprinkler piping in the renovated areas to facilitate the future provision of sprinklers throughout the facility in order to implement NIH policy to provide sprinkler protection in all occupied facilities. |
| | | X | | | The sprinkler pipe shall be Schedule 40 black steel or galvanized, except for installations where nonferrous materials are required. Schedule 5, Schedule 10, “light wall” designated, or plastic sprinkler pipe is not permitted. |
| | | | X | | Sprinkler system fittings shall meet the following requirements: Fittings into which sprinklers and sprinkler riser nipples are threaded shall be welded, threaded, or grooved-end type. Plain end fittings with mechanical couplings and fittings that use steel gripping devices to bite into the pipe when pressure is applied are not permitted. |
| | | | X | | Where pendent sprinklers are installed on exposed piping (in areas with concrete ceilings), tee and elbows to which sprinklers are connected shall have one-inch outlets and shall be provided with 25 mm (1 inch) by 12 mm (1/2 inch) hexagon reducing bushings to permit connection of 25 mm (1 inch) drop nipples in the future. |
| | | | X | | All concealed sprinkler piping and sprinkler piping in the stairwells, storage rooms, mechanical rooms, and utility rooms shall be painted red enamel. All other exposed sprinkler piping (outside of the stairwells) shall be painted to match the existing ceiling and red enamel bands 0.1 m wide shall be painted at 3.0 m intervals. In aesthetically sensitive areas, exposed sprinkler piping shall be painted to match the existing ceiling without red enamel bands. Valves, inspector test assemblies, low point drains, and auxiliary drains shall be provided with red enamel bands. |
| | | | X | | All new sprinkler systems shall have a central drain riser adjacent to the system riser, which shall be fully accessible to maintenance and safety personnel. With the exception of low point and auxiliary drains, all new system drain risers shall be hard-piped to an approved exterior location or to a safe location inside the building which shall accept full water flow without causing property damage or a safety hazard. |
| | | | X | | Quick-response type sprinklers are to be used throughout all NIH facilities, but standard-response type sprinklers shall be used in autoclave areas, electrical switchgear rooms, transformer rooms, electrical closets, freezers, cold rooms, and mechanical rooms. |
| | | | X | | Wave minimum Ordinary Hazard, Group 1 requirement. |

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE N/A | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | | Wave prohibition of sprinklers in elevator hoist ways and pits. |
| | | | X | | Waive wall mounted and peninsula shelving height policy. |
| | | | X | | Waive post indicator valve requirement. |
| | | | X | | Waive prohibition of Class II and Class III standpipe systems. |
| | | | X | | AHJ may require valves in standpipes at intermediate levels. |
| | | | X | | Waive prohibition of pressure reducing valves on standpipe systems. |
| | | | X | | Fire Department Connections (NFPA's 13 and & 14): At least one fire department connections (new building construction) shall be within 30.0 m of a fire hydrant. If any plan dimension of the building is greater than 46.0 m, then a second remote fire department connection shall be provided. |
| | | | X | | Fire Hydrants (NFPA 24): A minimum of two hydrants shall be provided within 150 m of each building. All parts of the building exterior shall be reached by hose lays from at least one fire hydrant of not over 400 m with consideration given to accessibility and obstructions. |
| | | | X | | Antifreeze systems are not permitted. |
| | | | X | | Pre-action suppression systems are permitted only on a case-by case basis. Coordinate with NIH DRM Committee for selection and use. |
| | | | X | | Heat trace tape is not permitted. |
| | | | X | | Alternative agent suppression systems (water mist, Halon replacements) are only permitted on a case-by-case basis. Coordinate with NIH DRM Committee for selection and use. |
| | | | X | | Fire Pumps (NFPA 20) Only electrically driven fire pumps shall be installed and shall be connected to an emergency power system (if available, see J.20 Fire Protection Emergency Power Requirements). The fire pump shall be sized to provide the most hydraulically most demanding sprinkler system. A separate hydraulic calculation for the standpipe risers and bulk mains shall be provided to demonstrate that NFPA 14 required fire hose valve flows can be met from fire apparatus connected to the building's Siamese connection. Assume a mobile fire apparatus supply of 1500 gpm @ 200 psi. |
| | | | X | | Wave key box requirement. |
| | | | X | | If the fire protective signaling system includes an automatic smoke detection system, other than smoke detection required for elevator fire protection, then an addressable multiplex fire alarm system shall be provided. When an addressable multiplex fire alarm system is modified, the architects/engineers design documents shall include system reprogramming, modification of graphic interfaces, and updating of system as-built drawings. |

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE N/A | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | | If the facility is considered a “high-rise building” in accordance with IBC, then an addressable multiplex fire alarm system shall be provided. The addressable multiplex shall be capable of transmitting a coded signal over a positive shunt non-interfering campus-wide McCulloh Loop system. The transmitting of the coded signal shall be an integral function of the addressable multiplex panel without the use of additional systems or foreign equipment. All fire alarm codes associated with the building fire alarm system shall be acquired from the NIH Fire Prevention Section. |
| | | | X | | All special purpose facilities that include animal facilities, health care occupancies, high-rise buildings, windowless structures, tunnels, and vaults shall be equipped with an addressable multiplex fire alarm system, fire department communication stations, and two-way occupant emergency communication. Upon an alarm, the fire alarm speakers are to sound a "slowwhoop" signal, at 90 to 110 dB, for four cycles, followed by a voice evacuation message. Upon completion of the voice message the slow-whoop shall resound and continue until the fire alarm control panel is reset or the "alarm silence" switch is activated. (This is not waived for animal facilities.) |
| | | | X | | When voice communication systems are provided, at least two audio channels shall be provided. The audio channels shall be suitably supervised. Voice paging shall take priority over all automatic messages. The voice communication system shall be equipped with backup amplifier(s) such that the loss of any amplifier shall result in automatic switching to the backup amplifier(s). The system’s amplifier(s) shall be sized to accommodate the activation of all notification appliances. Adjustable volume levels for notification devices is required. |
| | | | X | | Fire protective signaling systems shall have the following circuit supervision styles (NFPA 72):<br>- All signaling line circuits (SLC) shall meet Style 6 requirements.<br>- All panel-to-panel communication SLC circuits shall meet Style 7 requirements.<br>- All initiating device circuits (IDC) shall meet Style D requirements.<br>- All notification appliance circuits (NAC) shall meet Style Z requirements. |
| | | | X | | All fire alarm wiring shall be installed in 19.05 mm (3/4-inch) minimum conduit or electrical metallic tubing (EMT). All fire alarms wiring in damp locations (fire pump and valve rooms, at flow, and tamper switches) shall be installed in liquid-tight flexible metal conduit and liquid-tight device boxes. Flexible metal conduit is limited to 1.83 m and shall be secured per National Electric Code. |
| | | X | | | All concealed fire alarm conduit and conduit located in the stairwells, storage rooms, mechanical rooms, garages, and utility rooms shall be painted |

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE N/A | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | | | red enamel. All other exposed fire alarm conduit (outside of the stairwells) shall be painted to match the existing adjacent wall surface, and red enamel bands 0.10 m wide shall be painted at 3.0 m intervals. This painting requirement also applies to the pull boxes, junction boxes, mounting boxes and extensions. Red enamel bands shall not be painted on the pull boxes, junction boxes, mounting boxes, and extensions. (In the case of box covers, this waiver does not apply. Box covers must be red.) |
| | | | X | | General office areas are not to be equipped with smoke detection. |
| | | | X | | The fire alarm wire for 120V AC circuits shall be #12 AWG, solid copper, TFN insulation. The fire alarm wire for 24V DC (or less) circuits shall be #16 AWG, solid copper, TFN insulation or solid copper cable in strict accordance with written equipment manufacturer's requirements. |
| | | | X | | All fire alarm systems shall be equipped with a 2 minute time delay, such that all "trouble" alarms are transmitted to the NIH Fire Department between 120 and 200 seconds after onset of the trouble condition occurs. |
| | | | X | | Waive requirement for reporting to NIH campus wide fire alarm reporting system. |
| | | | X | | Waive prohibition of duce smoke detectors. |
| | | | X | | Waive requirement for recessed cabinet, the prohibition on cabinet locks and the prohibition of fire extinguisher in open garage. |
| | | | X | | Waive class A requirement. |
| | | | X | | Waive Class 1 requirement. |
| | | | X | | Electrical Receptacles for Fire Department Use: Provide single receptacle NEMA L5-20R, twist-lock, 125V AC receptacles at each standpipe system connection within stairwells and at 30 m intervals in the exit access corridors at each level for the operation of fire department electrical equipment in the event of an emergency. The receptacles shall be provided with a red cover plate and be suitably identified by the following lettered designation "For Fire Department Use Only." |
| | | | X | | Prohibition of self luminous exit signs is waived. |

# NIH DRM LEASED FACILITY WAIVER CHECKLIST ELECTRICAL

Instructions for use: The below checklist includes only those items that are waived. Every part of the NIH DRM not listed in the “Guide Reference” column on the table applies to all NIH projects. Where the table shows an "x" in the "all" column, the referenced paragraph is waived for any lease project regardless of the lease duration as described in the "description column". For example, in the architectural sheet, for DRM

reference, lease facilities in existing buildings are not required to conform to the thermal performance of windows, exterior doors, glazed panels and skylights. Because the description states existing facilities, new facilities would need to conform unless a variance is approved. Existing facilities would not need a variance when in nonconformance. In some cases the description summarizes or copies the part that is waived. For lines in the checklist where the "x" is in the "<=5" column, then the application is similar to that described above except that instead of waiving the requirement for all lease projects, these are only waived as described for leases that are 5 years or less. Likewise the "<=10" column are for waivers that only apply to leases with a 10 or less year duration.

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE N/A | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | | For comparison of systems, the life-cycle shall be waived to 15 to 20 years for all lease applications. |
| | X | | | | Redundancy |
| | | | | | Listed below are the exceptions to the NIH DRM only and use of the exception is optional. Regardless of the exceptions and any other requirements, all work must shall conform to the NEC. |
| | | | X | | Economic analysis for selection of building voltage |
| | | | X | | Analysis for step down transformers as large central units or as smaller distributed units |
| | | | X | | Requirement for power system study with SKM software. (A study is still required but use of SKM software is not.) |
| | | | X | | Submission for O&M manuals to Government if Government not performing the maintenance. |
| | | | X | | Paragraph specific to the NIH Bethesda campus is not applicable. NIH will not provide determination of service provider. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | While load figures can be used as a guide and for confirmation of calculated service sizing applicability, actual National Electrical Code [NEC] (NFPA 70) requirements for service sizing should be used since the Government is not the authority having jurisdiction. Some spare capacity is recommended to allow for anticipated changes in program function over the course of the lease term, typical of biomedical facility construction. |
| | | | X | | Paragraph specific to the NIH Bethesda campus is not applicable. |
| | | | X | | Switchgear is not required to be metal enclosed gear with draw out circuit breakers. |
| | | | X | | Bussing is not required to be copper, but is recommended to be copper. |
| | | | X | | Switchgear arrangement is not required to follow NIH network system arrangement. |
| | | | X | | Dual ground bus arrangement is not required for a non-spot network system. |
| | | | X | | Full metering is not required, nor is any SCADA metering, monitoring or control. |
| | | | X | | Switchboard construction would be allowed. |

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE N/A | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | | Switchgear lineups do not required rail assembly or lifting hoist. |
| | | | X | | Any specialized tools for installation, maintenance, calibration, or testing are not required to be provided to NIH, but should be provided to building owner. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Work space clearances beyond NEC requirements. |
| | | | X | | Ventilation, temperature and humidity requirements for electrical rooms. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Testing is not an NIH requirement if the distribution system is not NIH owned. |
| | | | X | | Wire color coding does not necessarily have to follow the NIH coding indicated, but must be consistent throughout a facility, and comply with NEC where applicable. |
| | | | X | | Conduit size beyond NEC required minimum sizing. |
| | | | X | | Electrical metallic tubing fittings are not required to be compression type. |
| | | | X | | Conduit types not specific to biomedical facilities shall conform to NEC but not necessarily to DRM. |
| | | | X | | Manhole and handhole spacing and wiring pulling requirements. |
| | | | X | | Copper requirement for busway. |
| | | | X | | Cable tray requirement. (The only requirement for telecommunication cabling is some type of wiring management system must be provided.) |
| | | | X | | Circuit breakers are not required to have a dc rating for the frame series (i.e. E-frame). |
| | | | X | | Not every panelboard is required to have a main circuit breaker. |
| | | | X | | Copper bussing requirement. |
| | | | X | | Full piano hinged trim requirement for panelboards 400 amperes and above. |
| | | | X | | Closet sizing shall be such to meet NEC required minimum clearances and work space requirements. |
| | | | X | | Panelboard locations do not have to meet NIH maximum distances for devices, so long as voltage drop following NEC requirements is accommodated. |
| | | | X | | With the exceptions of emergency power and isolated ground receptacles, device color coding is not required to follow NIH standards. |
| | | | X | | Information specifically related to NIH Building 10. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Requirements indicated for specialty twist lock fire department receptacles is by a Montgomery County (Maryland) Executive Order, and is only required for facilities in that county. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Paragraph specific to the NIH Bethesda campus. |
| | | | X | | Motor voltages shall comply with available building voltages. |
| | | | X | | Motor starter accessories are not required to com- |

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE N/A | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | | | ply with those indicated. |
| | | | X | | Motor control centers are not required in lieu of grouping of individual motor starters. |
| | | | X | | Contact with NIH senior electrical engineer is not necessary. |
| | | | X | | Site lighting and exterior lighting types. |
| | | | X | | Lighting pollution and cut off shielding. |
| | | | X | | Site lighting pole tag. |
| | | | X | | Site lighting spacing as shown is waived but design shall as a minimum follow IESNA recommendations. |
| | | | X | | Street lighting circuits, controls and wiring. |
| | | | X | | Parking garage lighting and control. |
| | | | X | | Connections to lighting fixtures. |
| | | | X | | Site lighting circuit voltages and information from NIH project officer and NIH electric shop. |
| | | | X | | Exterior lighting control. |
| | | | X | | Light pole maximum height. |
| | | | X | | While load figures can be used as a guide and for confirmation of calculated service sizing applicability, actual National Electrical Code [NEC] (NFPA 70) requirements for service sizing should be used since the Government is not the authority having jurisdiction. Some spare capacity is recommended to allow for anticipated changes in program function over the course of the lease term, typical of biomedical vivarium facility construction. |
| | | | X | | Racking system requirement. |
| | | | X | | While load figures can be used as a guide and for confirmation of calculated service sizing applicability, actual National Electrical Code [NEC] (NFPA 70) requirements for service sizing should be used since the Government is not the authority having jurisdiction. Some spare capacity is recommended to allow for anticipated changes in program function over the course of the lease term, typical of biomedical laboratory facility construction. |
| | | | X | | Surface metal raceway requirement. |
| | | | X | | Surface metal raceway circuiting with local overcurrent protective devices. |
| | | | X | | 60A., 3 phase, 4 wire circuit minimum per laboratory. |
| | | | X | | Number of circuits for computers and receptacles. |
| | | | X | | 20A., 120V. circuit in junction box on ceiling of each lab module. |
| | | | X | | Any emergency powered lighting fixtures required in BSL-2 laboratories is at program discretion, unless required by Code for egress lighting. At least one lighting fixture per BSL-3 and BSL-4 laboratories per module is required on generator emergency power - additionally, these same fixtures are also required to be provided with a self testing emergency battery ballast to carry through the generator start time without having these areas in complete darkness. |

# NIH DRM LEASED FACILITY WAIVER CHECKLIST ENVIRONMENTAL

Instructions for use: The below checklist includes only those items that are waived. Every part of the NIH DRM not listed in the “Guide Reference” column on the table applies to all NIH projects. Where the table shows an "x" in the "all" column, the referenced paragraph is waived for any lease project regardless of the lease duration as described in the "description column". For example, in the architectural sheet, for DRM reference, lease facilities in existing buildings are not required to conform to the thermal performance of windows, exterior doors, glazed panels and skylights. Because the description states existing facilities, new facilities would need to conform unless a variance is approved. Existing facilities would not need a variance when in nonconformance. In some cases the description summarizes or copies the part that is waived. For lines in the checklist where the "x" is in the "<=5" column, then the application is similar to that described above except that instead of waiving the requirement for all lease projects, these are only waived as described for leases that are 5 years or less. Likewise the "<=10" column are for waivers that only apply to leases with a 10 or less year duration.

| CHECK BOX | LEASE DURATION (YEARS) | | | DRM REFERENCE | DESCRIPTION |
|---|---|---|---|---|---|
| | <=5 | <=10 | All | | |
| | | | X | N.2.10.2 | Leased facilities shall provide the necessary containers and collection services to meet recycling requirements of the Montgomery County Business Recycling Regulations. |

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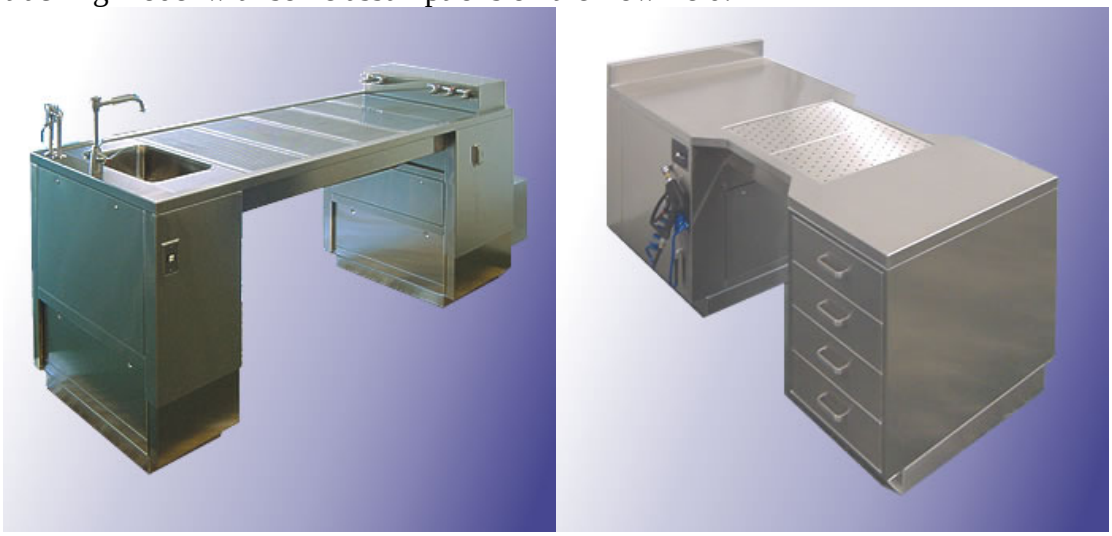
# Appendix H

**Down Draft Table Position Paper**

# Downdraft Table Particle Capture Efficiency Calculation

**Farhad Memarzadeh, Ph.D., P.E.**
**Division of Technical Resources**
**Office of Research Facilities**
**National Institutes of Health**

To calculate capture efficiency of a downdraft table, the presented method used a particle tracking model with some assumptions on the flow field.



## Assumptions:

1). Flow around the table: uniform, but not necessarily vertical, horizontal velocity components of the airflow can be considered. No pressure gradient in the flow field.

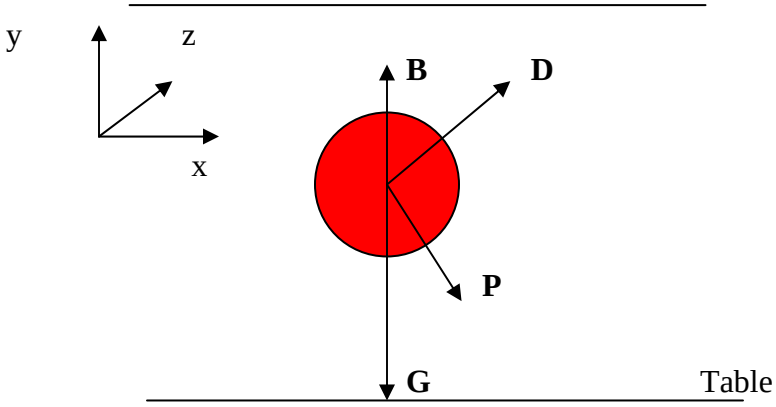
2). Particles can have non-zero initial velocity.

3). Particles will not collide to each other

4). When a particle hit table, the particle is considered captured.

## Particle Movement Calculation

**Forces that exerted on a moving particle:**




**G**: Gravity force
**B**: Buoyancy force
**D**: Drag Force
**P**: Pressure Force (caused by the pressure gradient in the flow field).

Neglected forces are: Additional inertia force, Basset Force, Magnus Force, Saffman Forces, Lift force.

**Particle Motion Equation:**

$$\sum \mathbf{F} = m\mathbf{a} = \mathbf{G} + \mathbf{B} + \mathbf{D} + \mathbf{P}$$

$$m\mathbf{a} = \frac{1}{6}\pi\, d^3 \rho_p \frac{d\mathbf{u}_p}{dt}$$

$$\mathbf{G} = \rho_p \mathbf{g} V$$

$$\mathbf{B} = -\rho_g \mathbf{g} V$$

$$\mathbf{D} = \frac{1}{8}\pi C_D d^2 \rho_g \left|\mathbf{u}_g - \mathbf{u}_p\right| (\mathbf{u}_g - \mathbf{u}_p)$$

$$\mathbf{P} = 0$$

$C_D$ can be calculated by either Clift and Gauvin's formula or Putnam's formula:

*Clift and Gauvin's formula*

$$C_D = f\frac{24}{\mathrm{Re}_r}$$

$$f = 1 + 0.15\,\mathrm{Re}_r^{0.687} + 0.0175\frac{\mathrm{Re}_r}{1 + 42500\,\mathrm{Re}_r^{-1.16}}$$

*Putnum's formula*

$$C_D = f\frac{24}{\mathrm{Re}_r}$$

$$f = 1 + \frac{1}{6}\mathrm{Re}_r^{2/3}$$

Where $\mathrm{Re}_r$ is the Reynolds number based on relative velocity

$$\mathrm{Re}_r = \frac{\rho_g \left|\mathbf{u}_g - \mathbf{u}_p\right| d}{\mu}$$

When expressed in three directions form, the formula becomes

**X:** $$\frac{du_{px}}{dt} = \frac{3C_D\rho_g}{4d\rho_p}\sqrt{(u_{gx}-u_{px})^2 + (u_{gy}-u_{py})^2 + (u_{gz}-u_{pz})^2}\,(u_{gx}-u_{px})$$

**Y:** $$\frac{du_{py}}{dt} = -\frac{\rho_p - \rho_g}{\rho_p}g + \frac{3C_D\rho_g}{4d\rho_p}\sqrt{(u_{gx}-u_{px})^2 + (u_{gy}-u_{py})^2 + (u_{gz}-u_{pz})^2}\,(u_{gy}-u_{py})$$

**Z:** $$\frac{du_{pz}}{dt} = \frac{3C_D\rho_g}{4d\rho_p}\sqrt{(u_{gx}-u_{px})^2 + (u_{gy}-u_{py})^2 + (u_{gz}-u_{pz})^2}\,(u_{gz}-u_{pz})$$

**Numerical Solution**

*Simple explicit first order differencing scheme:*

Use $\frac{d\mathbf{u}_p}{dt} = \frac{\mathbf{u}_p^{n+1} - \mathbf{u}_p^n}{\Delta t}$ and get:

$$u_{px}^{n+1} = \Delta t\left\{u_{px}^n + \frac{3C_D\rho_g}{4d\rho_p}\sqrt{(u_{gx}-u_{px}^n)^2+(u_{gy}-u_{py}^n)^2+(u_{gz}-u_{pz}^n)^2}\,(u_{gx}-u_{px}^n)\right\}$$

$$u_{py}^{n+1} = \Delta t\left\{u_{py}^n - \frac{\rho_p-\rho_g}{\rho_p}g + \frac{3C_D\rho_g}{4d\rho_p}\sqrt{(u_{gx}-u_{px}^n)^2+(u_{gy}-u_{py}^n)^2+(u_{gz}-u_{pz}^n)^2}\,(u_{gy}-u_{py}^n)\right\}$$

$$u_{pz}^{n+1} = \Delta t\left\{u_{pz}^n + \frac{3C_D\rho_g}{4d\rho_p}\sqrt{(u_{gx}-u_{px}^n)^2+(u_{gy}-u_{py}^n)^2+(u_{gz}-u_{pz}^n)^2}\,(u_{gz}-u_{pz}^n)\right\}$$

This method requires relatively small time steps to keep the solution stable, currently 0.0001s is found sufficient.

## Capture Efficiency Calculation

Capture efficiency(percentage) can be easily obtained by calculate a single particle's drift distance in horizontal directions. For example, if a particle is released from $X_0$, $Y_0$, $Z_0$ in space, we just need to calculate how much distance the particle has drifted from $X_0$, $Z_0$, given the fixed vertical falling height. Assume the trajectory of the particle cross (X0-$X_d$,0, $Z_0$-$Z_d$), then the capture percentage is simply

$$C = \frac{L - X_d}{L}\frac{W - Z_d}{W} \times 100\%$$

where L and W are length and width of the draft table.

In the spreadsheet, the ranges of particle releasing and landing are represented by two rectangles.

## Nomenclature

**G**: Gravity force vector
**B**: Buoyancy force vector
**D**: Drag Force vector
**P**: Pressure Force (caused by the pressure gradient in the flow field) vector
**a**: Accelaration of particle vector
m: Mass of particle
V: Volume of particle
d: Particle diameter
$\rho_p$: Density of particle
$\rho_g$: Density of Gas (air)
$C_D$: Drag coefficient of particle
f: Resistance factor
$Re_r$: Reynolds number based on relative speed
$\mathbf{u}_g$: Gas velocity vector ($u_{gx}$,$u_{gy}$,$u_{gz}$ are velocity components in x,y,z directons)
$\mathbf{u}_p$: Particle velocity vector
$\mathbf{u}_p^{n+1}$: Particle velocity vector in the new time step
$\Delta t$: Time step
L: Length of the downdraft table (center area where the flow is drawing downwards)
W: Width of the downdraft table (center area where the flow is drawing downwards)
$X_0$, $Y_0$, $Z_0$: Release location of particle
$X_d$,$Z_d$: Drift distance in X, Z directions.
C: Capture efficiency

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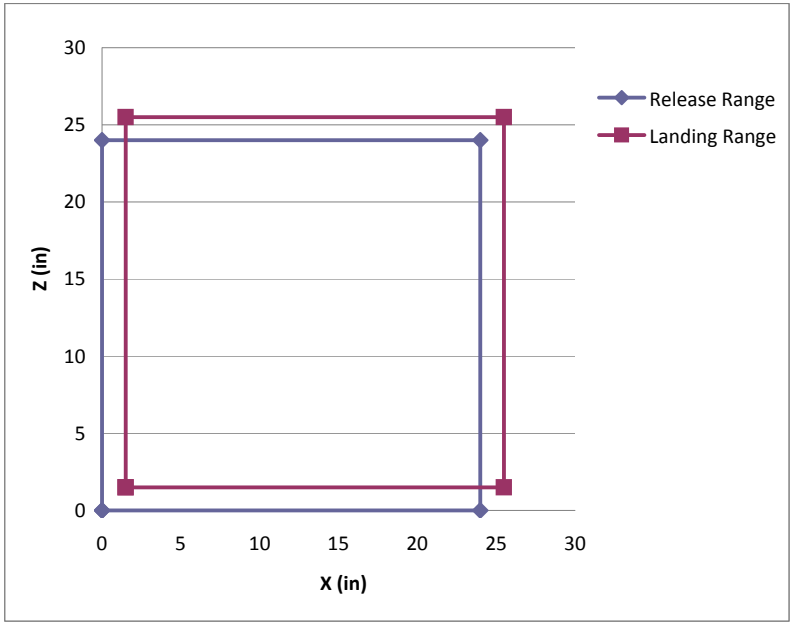
## User Input

| Table Dimension | | |
|---|---|---|
| Length X | 24 | in |
| Width Z | 24 | in |

| Airflow Condition around Table | | |
|---|---|---|
| Air Density | 1.1614 | kg/m^3 |
| Air Viscosity | 1.84E-05 | Ns/m^2 |
| **Vertical Speed Vy** | **-50** | ft/min |
| Horizontal Speed Vx | 15 | ft/min |
| Horizontal Speed Vz | 15 | ft/min |

| Particle Information | | |
|---|---|---|
| Size | 5 | micron |
| Density | 1000 | kg/m^3 |
| **Release Height** | **5** | in |
| **Particle Initial Velocity** | | |
| Vertical Speed Vy | 0 | ft/min |
| Horizontal Speed Vx | 0 | ft/min |
| Horizontal Speed Vz | 0 | ft/min |




## Output

| | |
|---|---|
| Drift Length X | 1.50 in |
| Drift Length Z | 1.50 in |
| Drift Length | 2.12 in |
| **Capture Percentage** | **87.92** % |

| | Release Range | | Landing Range | |
|---|---|---|---|---|
| | X | Z | X | Z |
| Corner 1 | 0 | 0 | 1.50 | 1.50 |
| Corner 2 | 24 | 0 | 25.50 | 1.50 |
| Corner 3 | 24 | 24 | 25.50 | 25.50 |
| Corner 4 | 0 | 24 | 1.50 | 25.50 |
| Corner 1 | 0 | 0 | 1.50 | 1.50 |

Particle Trajectory

## User Input

| Table Dimension | | |
|---|---|---|
| Length X | 24 | in |
| Width Z | 24 | in |

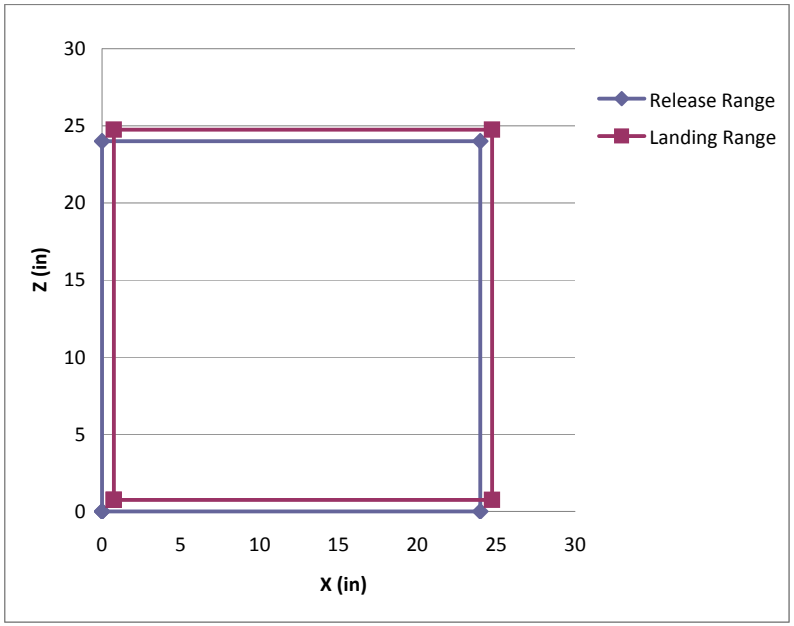
| Airflow Condition around Table | | |
|---|---|---|
| Air Density | 1.1614 | kg/m^3 |
| Air Viscosity | 1.84E-05 | Ns/m^2 |
| **Vertical Speed Vy** | **-100** | ft/min |
| Horizontal Speed Vx | 15 | ft/min |
| Horizontal Speed Vz | 15 | ft/min |

| Particle Information | | |
|---|---|---|
| Size | 5 | micron |
| Density | 1000 | kg/m^3 |
| **Release Height** | **5** | in |
| **Particle Initial Velocity** | | |
| Vertical Speed Vy | 0 | ft/min |
| Horizontal Speed Vx | 0 | ft/min |
| Horizontal Speed Vz | 0 | ft/min |

## Output

| | | |
|---|---|---|
| Drift Length X | 0.75 | in |
| Drift Length Z | 0.75 | in |
| Drift Length | 1.06 | in |
| **Capture Percentage** | **93.85** | % |

| | Release Range | | Landing Range | | |
|---|---|---|---|---|---|
| | X | Z | X | Z | |
| Corner 1 | 0 | 0 | 0.75 | 0.75 | |
| Corner 2 | 24 | 0 | 24.75 | 0.75 | |
| Corner 3 | 24 | 24 | 24.75 | 24.75 | |
| Corner 4 | 0 | 24 | 0.75 | 24.75 | |
| Corner 1 | 0 | 0 | 0.75 | 0.75 | |




Particle Trajectory

# Appendix I

Biosafety Safety Cabinet (BSC) Placement
Requirements for new Buildings and Renovations

# Biosafety Cabinet (BSC) Placement Requirements for new Buildings and Renovations

**NATIONAL INSTITUTES of HEALTH**
**Farhad Memarzadeh, Ph.D., P.E.**

**Division of Technical Recourses**
**Office of Research Facilities**

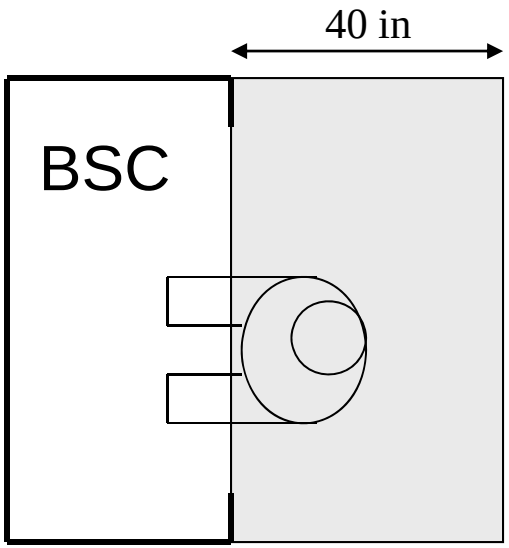
*Refrence:*

*Microbiological Safety Cabinets: Recommendations for Cabinet Installation.* British Standards Institution, BS 5726:2005.
*Methodology for Optimization of Laboratory Hood Containment*. Memarzadeh, F. National Institutes of Health, 1996.

# DO’s

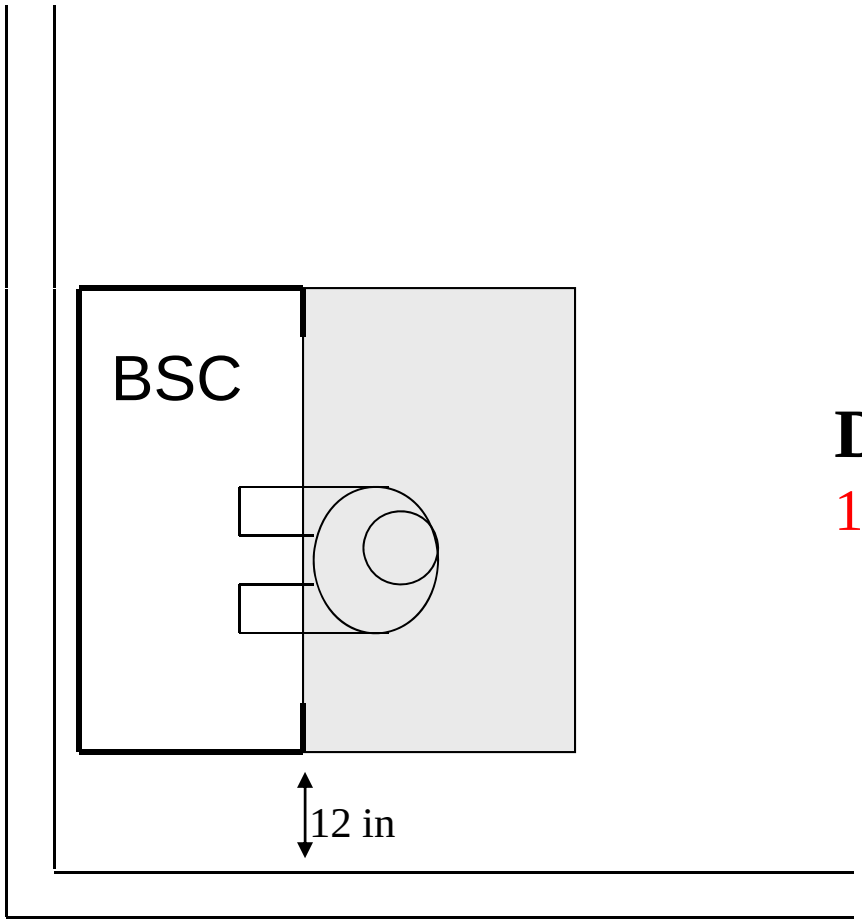
## Requirements for BSC Placement

# Workspace Specifications



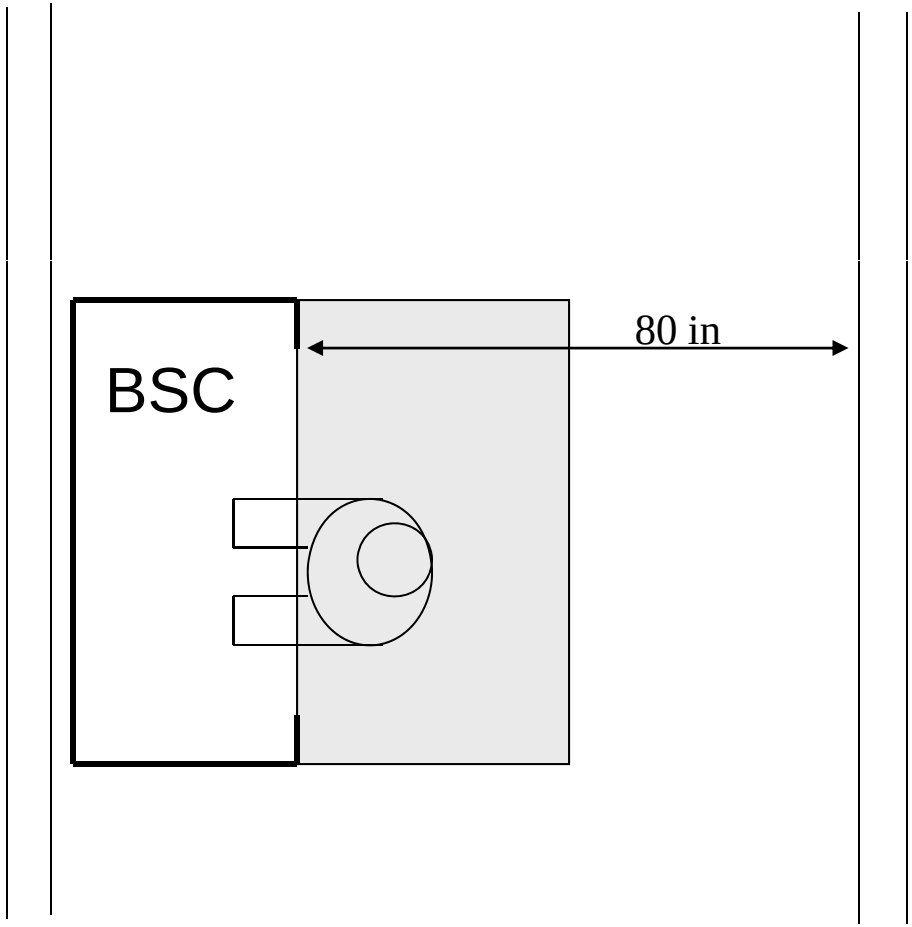

**DO** Maintain an undisturbed space of 40" around BSC.

# Distance to Adjacent Wall



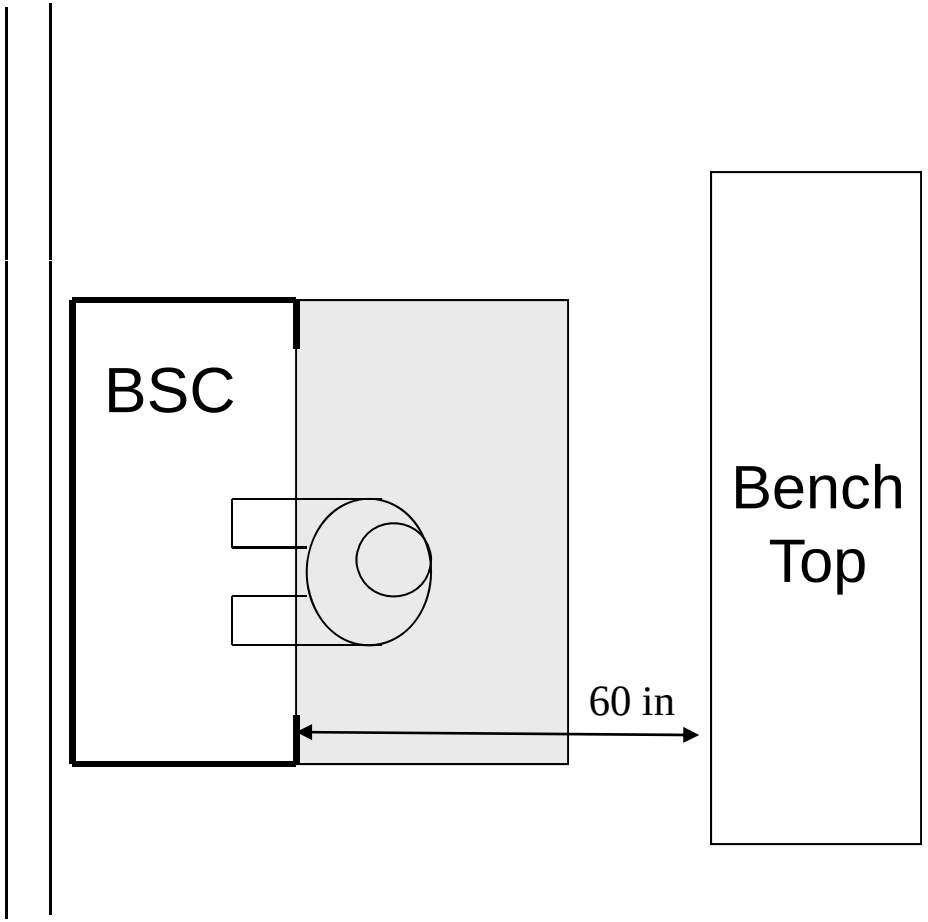

**DO** Maintain a distance of 12" to adjacent walls.

# Distance to Opposing Walls



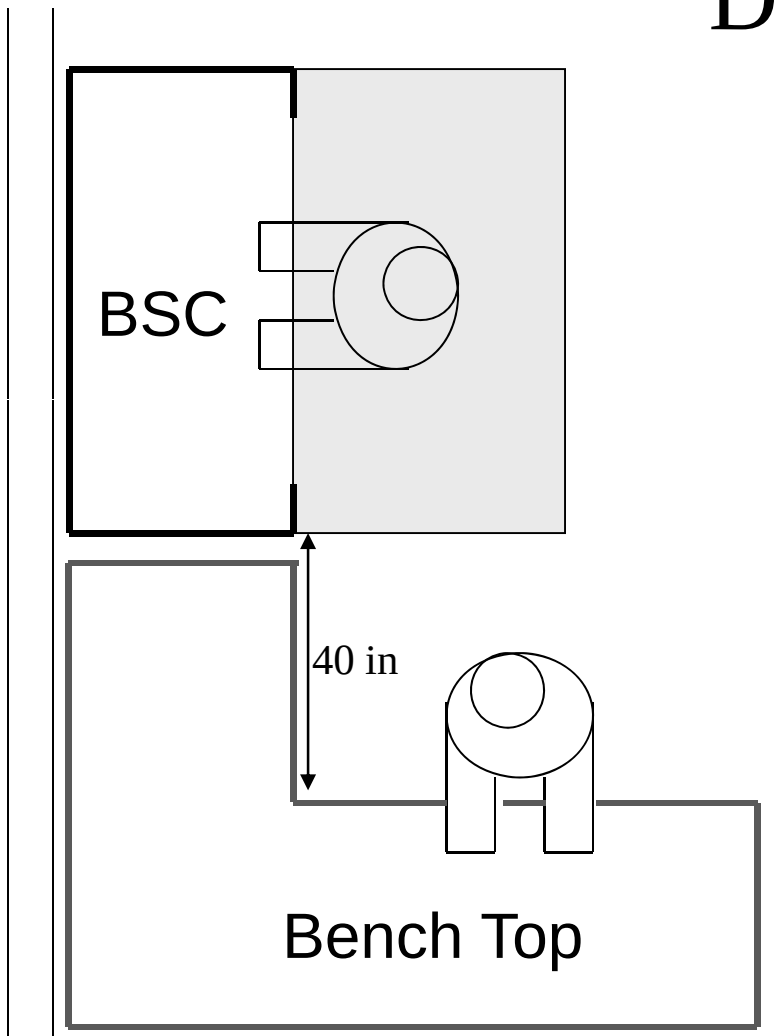

**DO** Place BSCs at least 80" from opposing walls.

# Distance to Bench Top



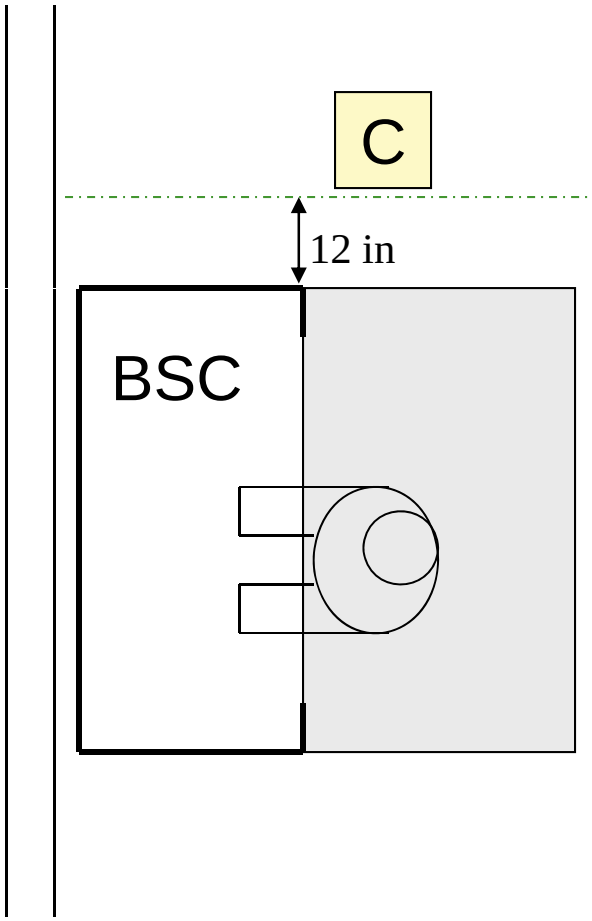

**DO** Place BSCs at least 60" to opposing bench tops or areas with occasional traffic.

# Distance to Bench Top



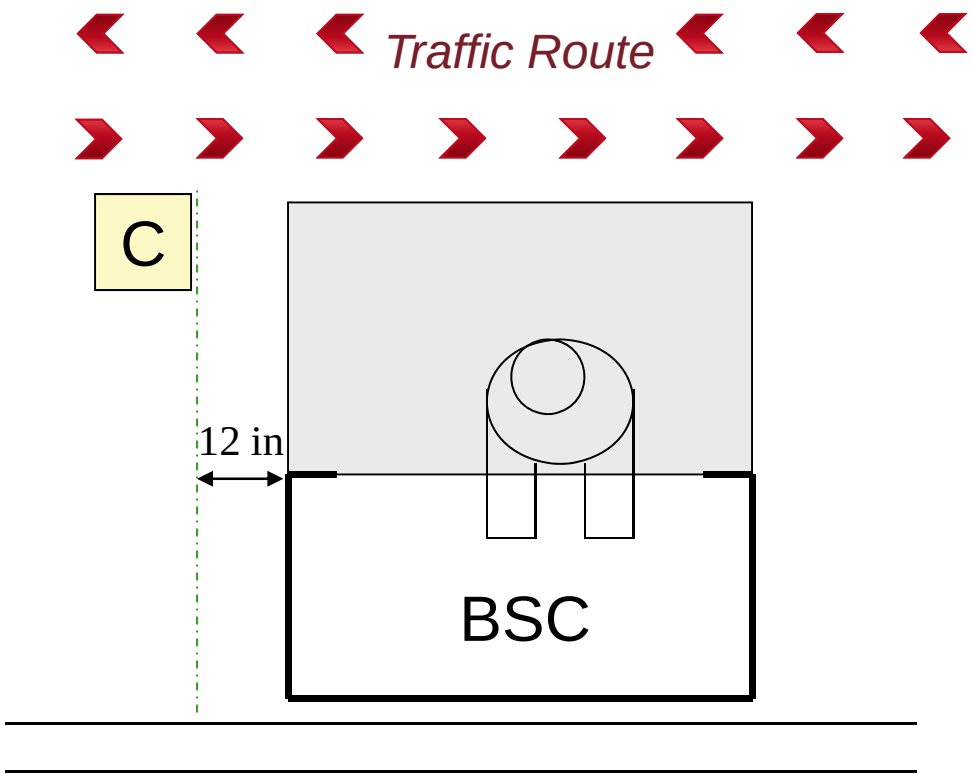

**DO** Maintain a distance of 40” between BSC and bench top along perpendicular wall.

# Distance to Columns




**DO** Maintain a distance of 12” to columns to avoid disturbance to BSC airflow.

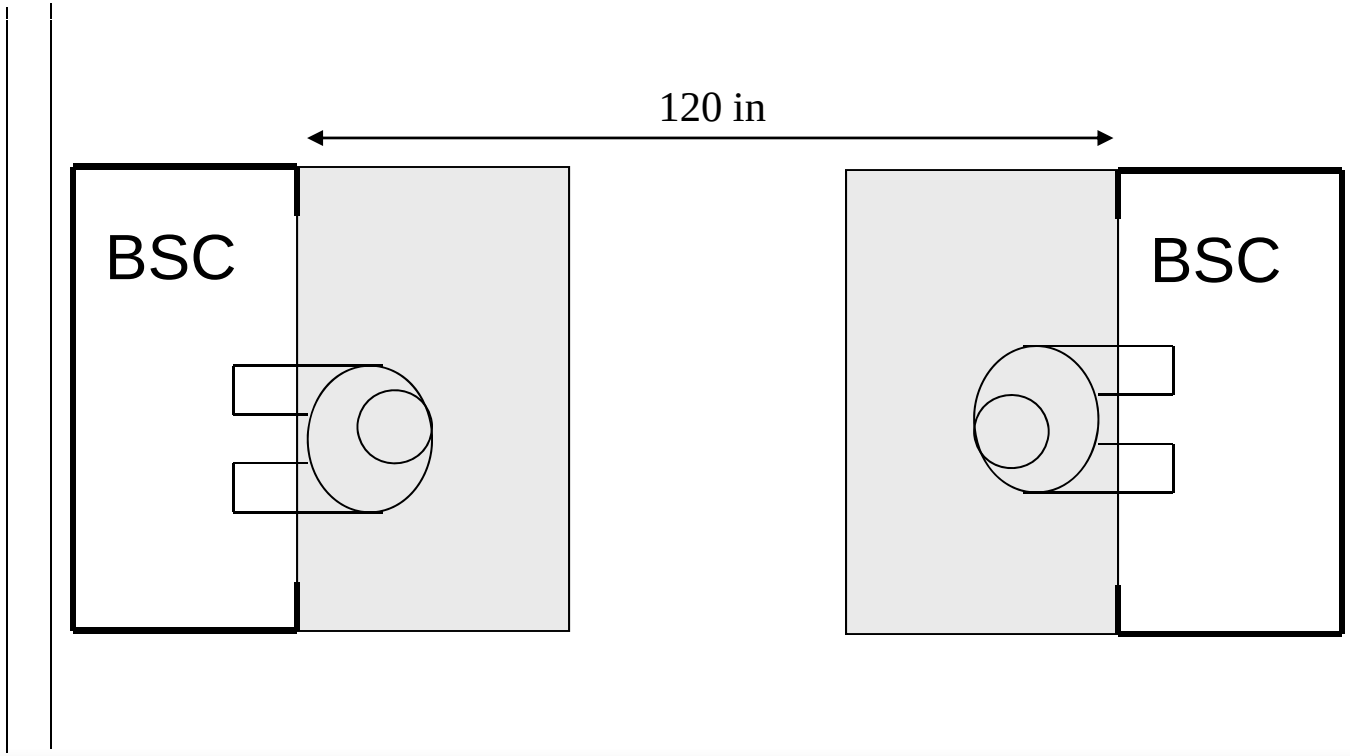
# Distance to Columns




**NOTE:** Columns at a distance of 12” can aid in defining traffic routes.

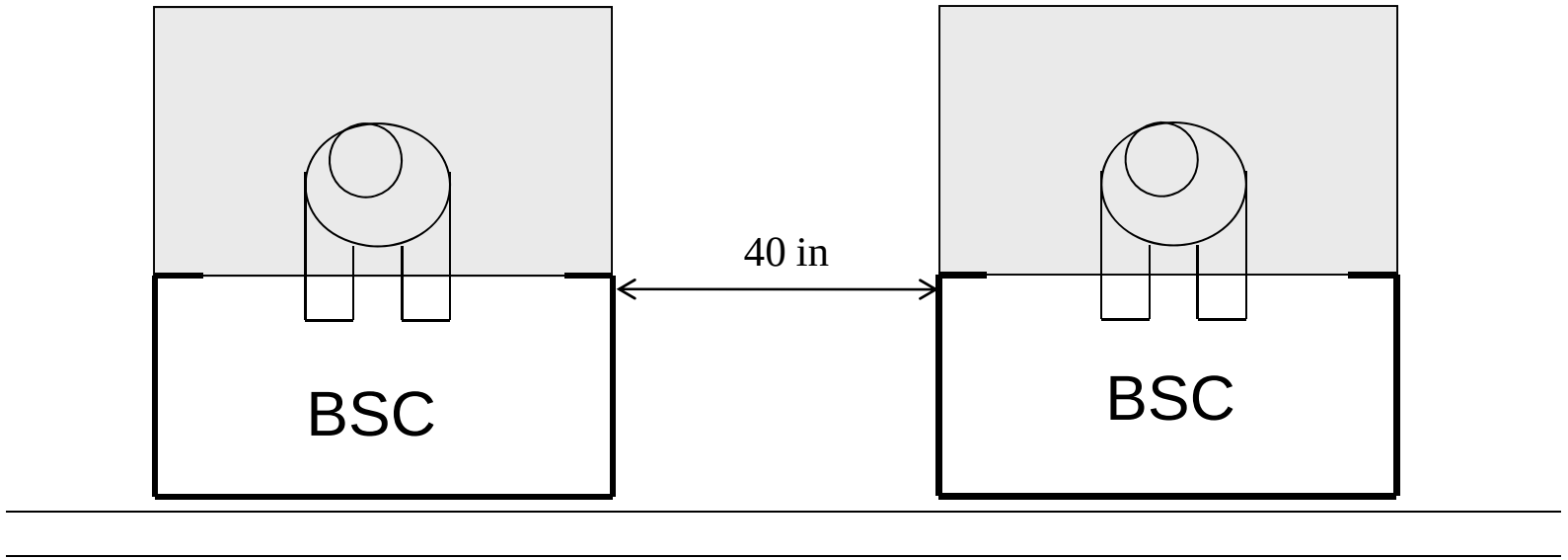
# BSC Placement Along Opposing Walls

**DO** Maintain a distance of 120” between opposing BSCs.

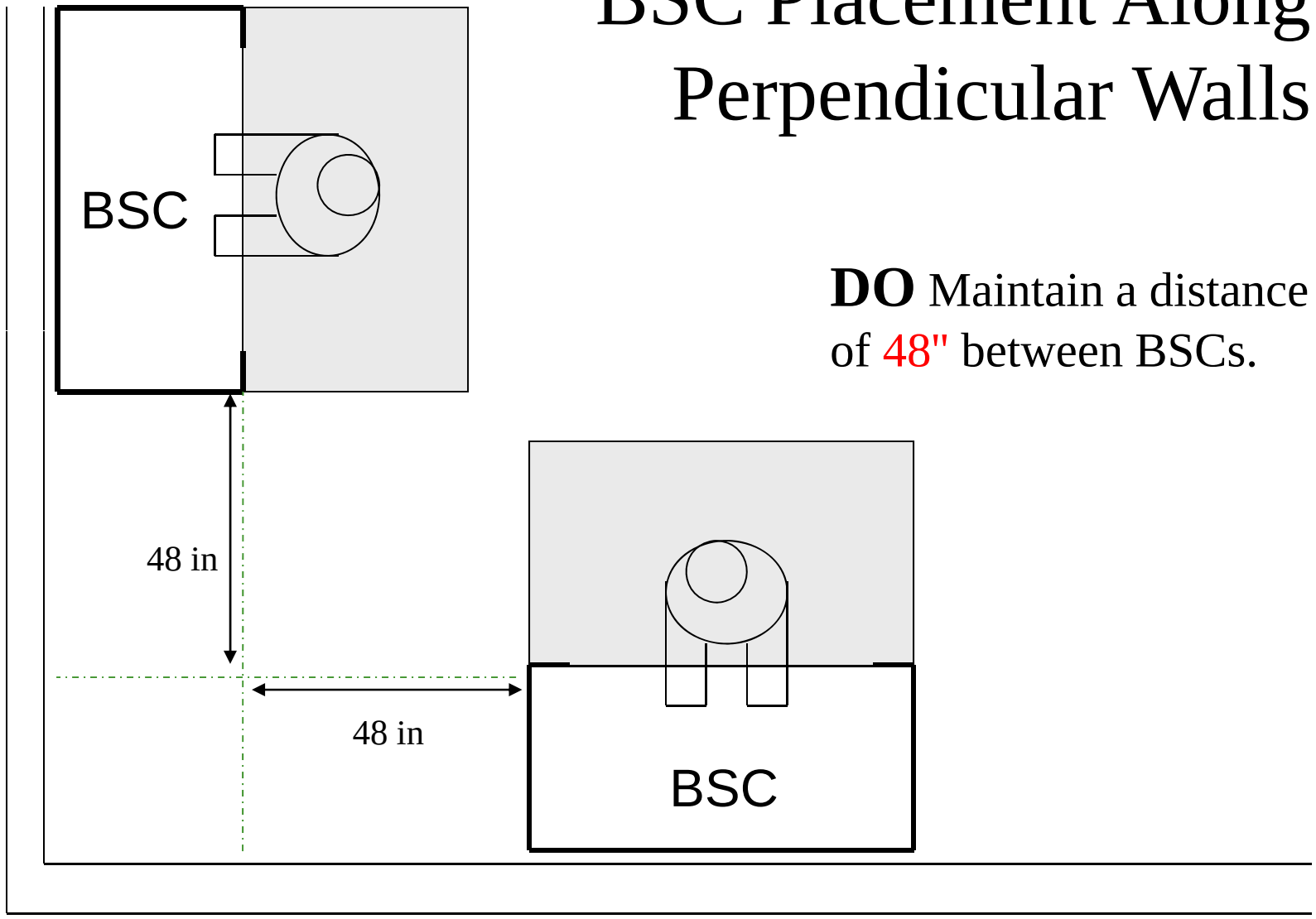


# BSC Placement Along Same Wall

**DO** Maintain a distance of 40” between BSCs along same wall.



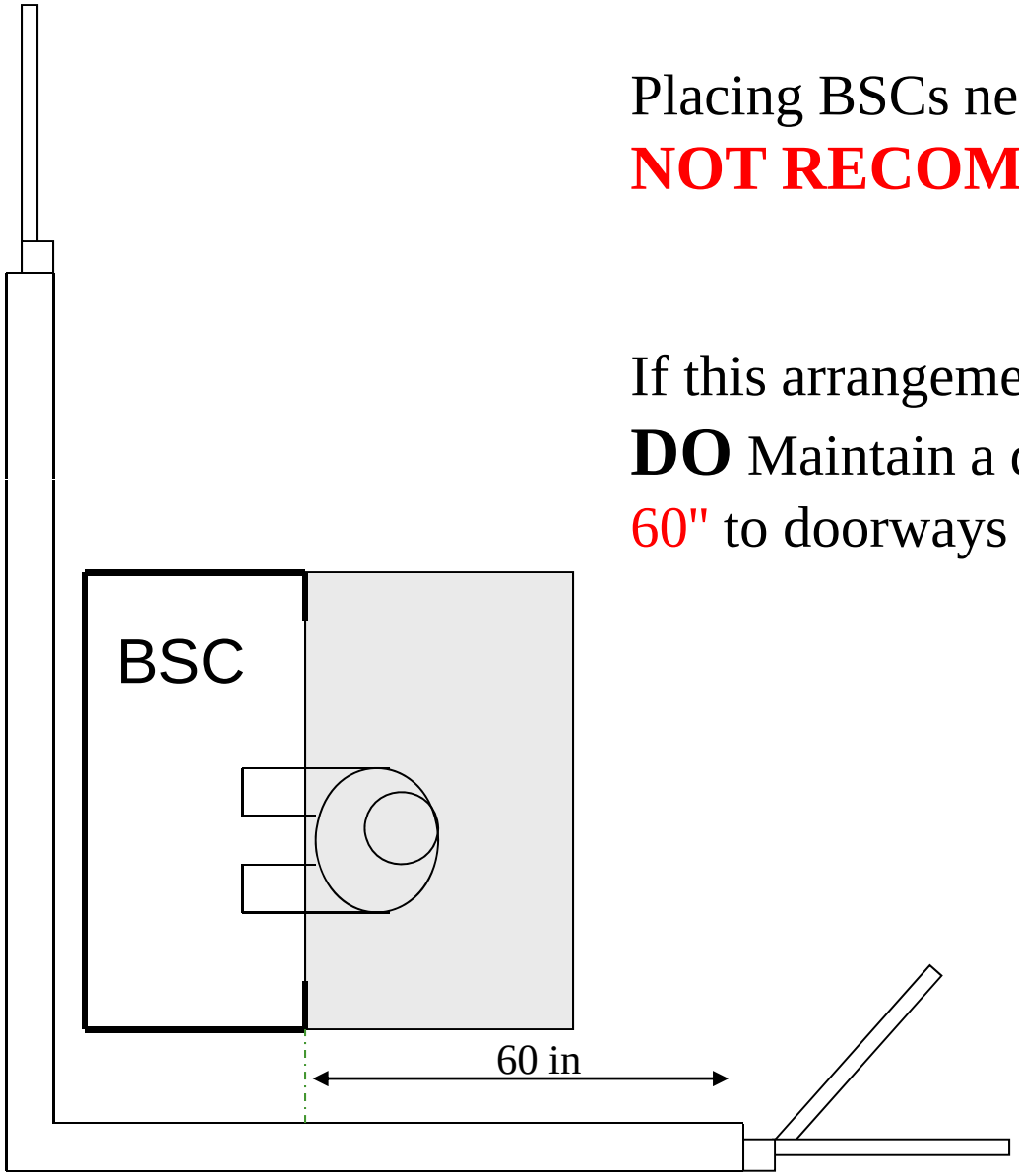
# BSC Placement Along Perpendicular Walls




**DO** Maintain a distance of 48" between BSCs.

# DONT's

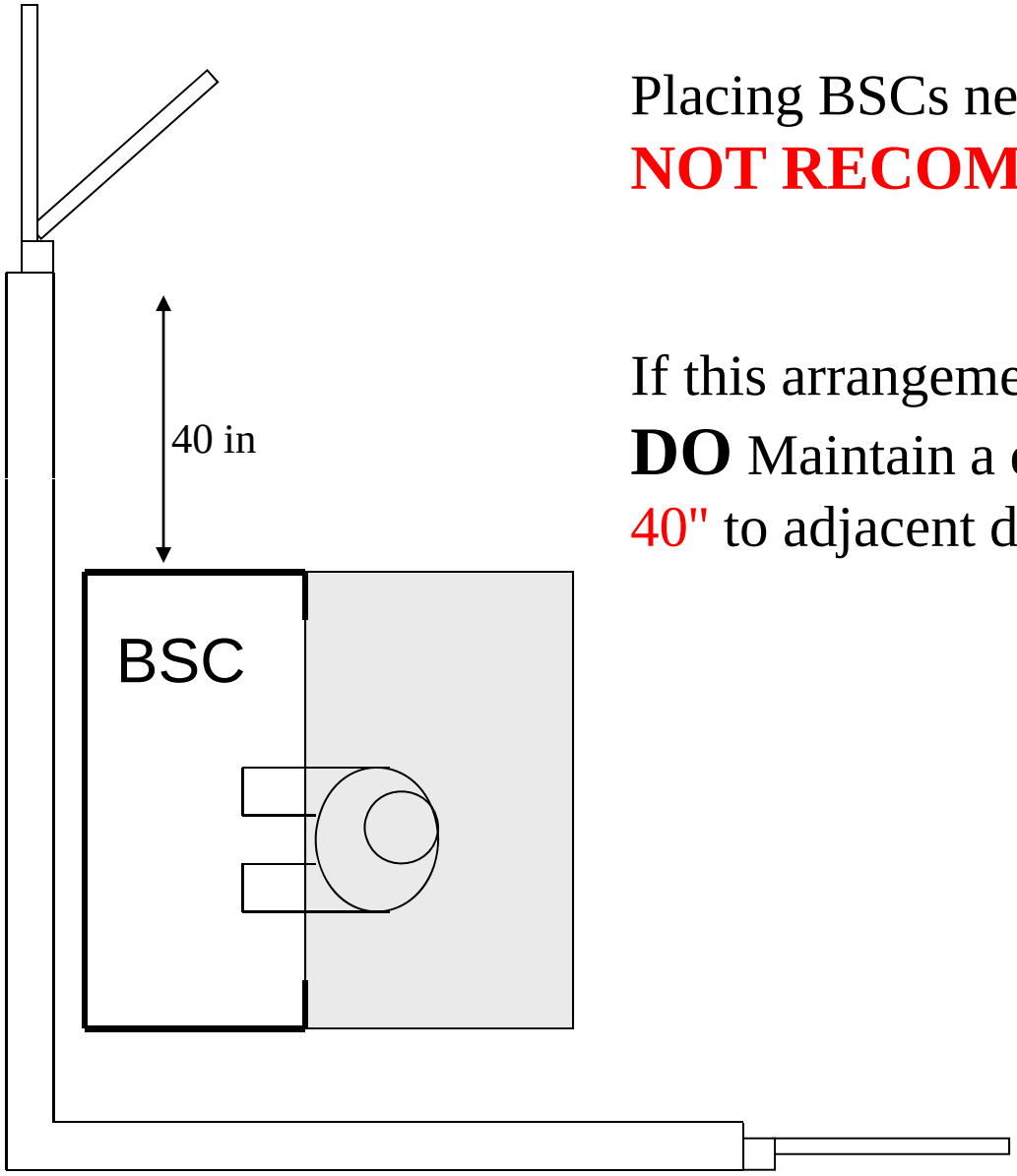
## BSC Arrangements to Avoid




Placing BSCs near One entryways is **NOT RECOMMENDED.**

If this arrangement is absolutely necessary:

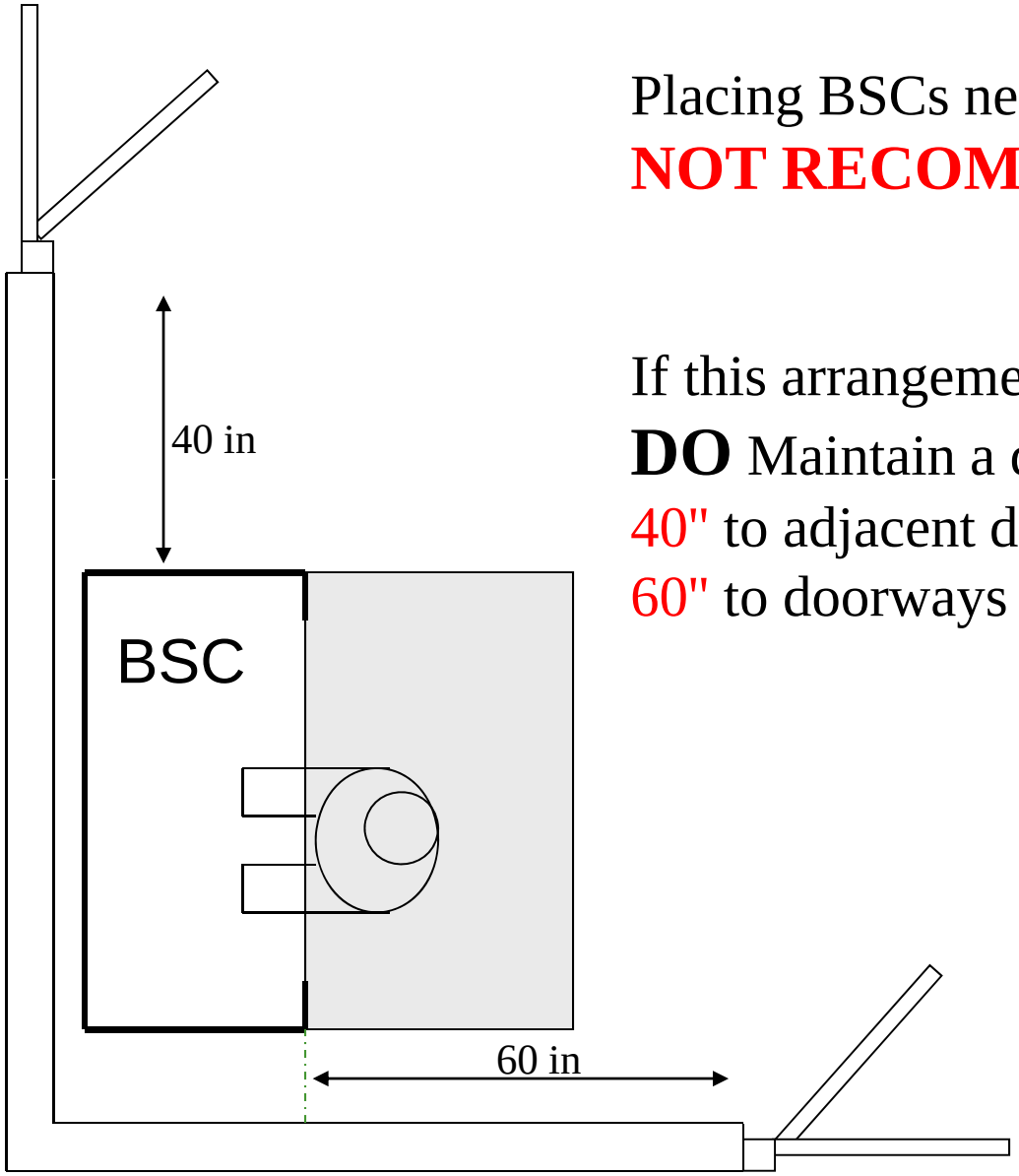
**DO** Maintain a distance of 60" to doorways behind workspace.




Placing BSCs near one entryways is **NOT RECOMMENDED.**

If this arrangement is absolutely necessary:

**DO** Maintain a distance of 40" to adjacent doorways



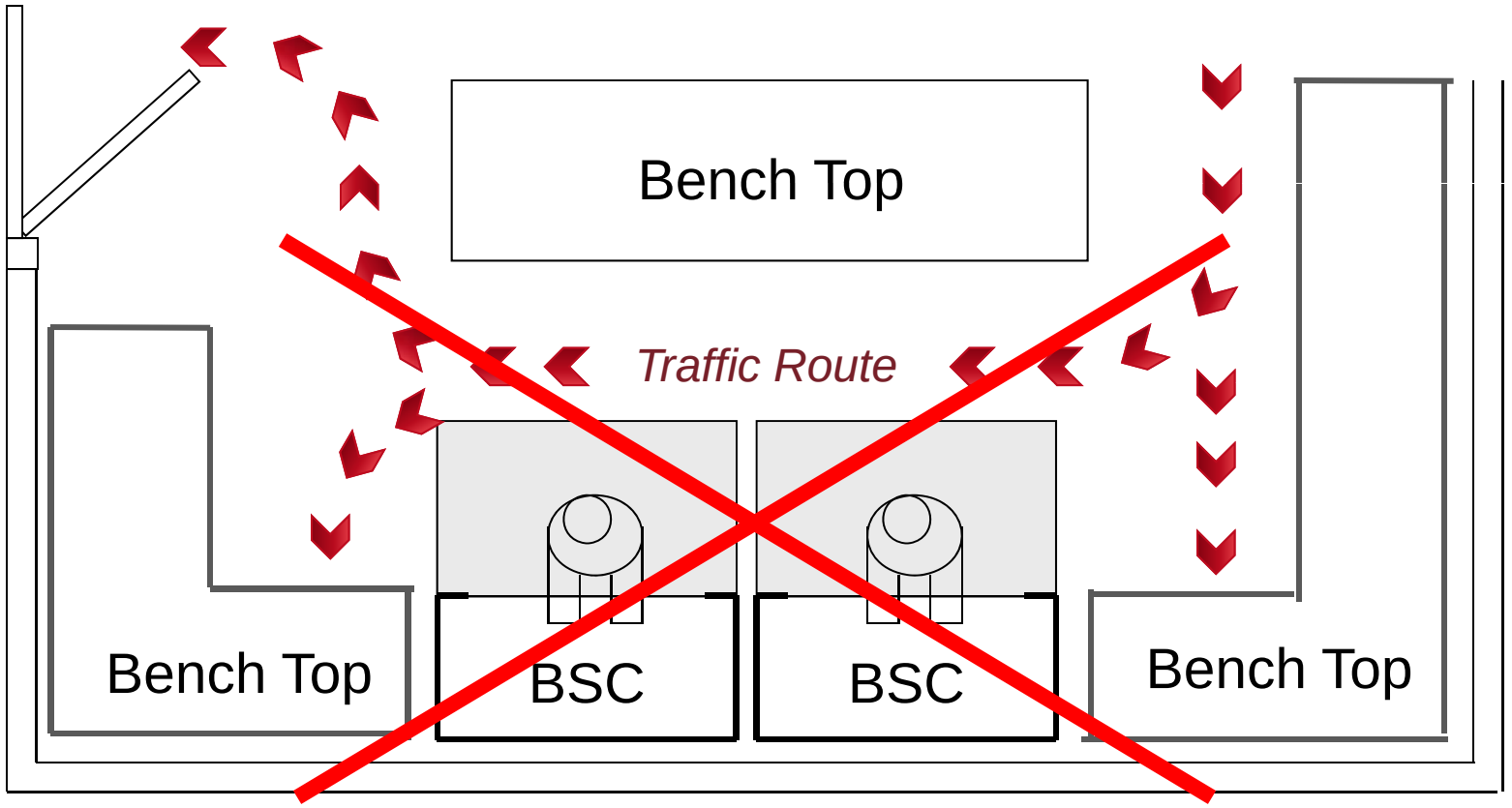

Placing BSCs near two entryways is **NOT RECOMMENDED.**

If this arrangement is absolutely necessary:

**DO** Maintain a distance of
40" to adjacent doorways and
60" to doorways behind workspace.

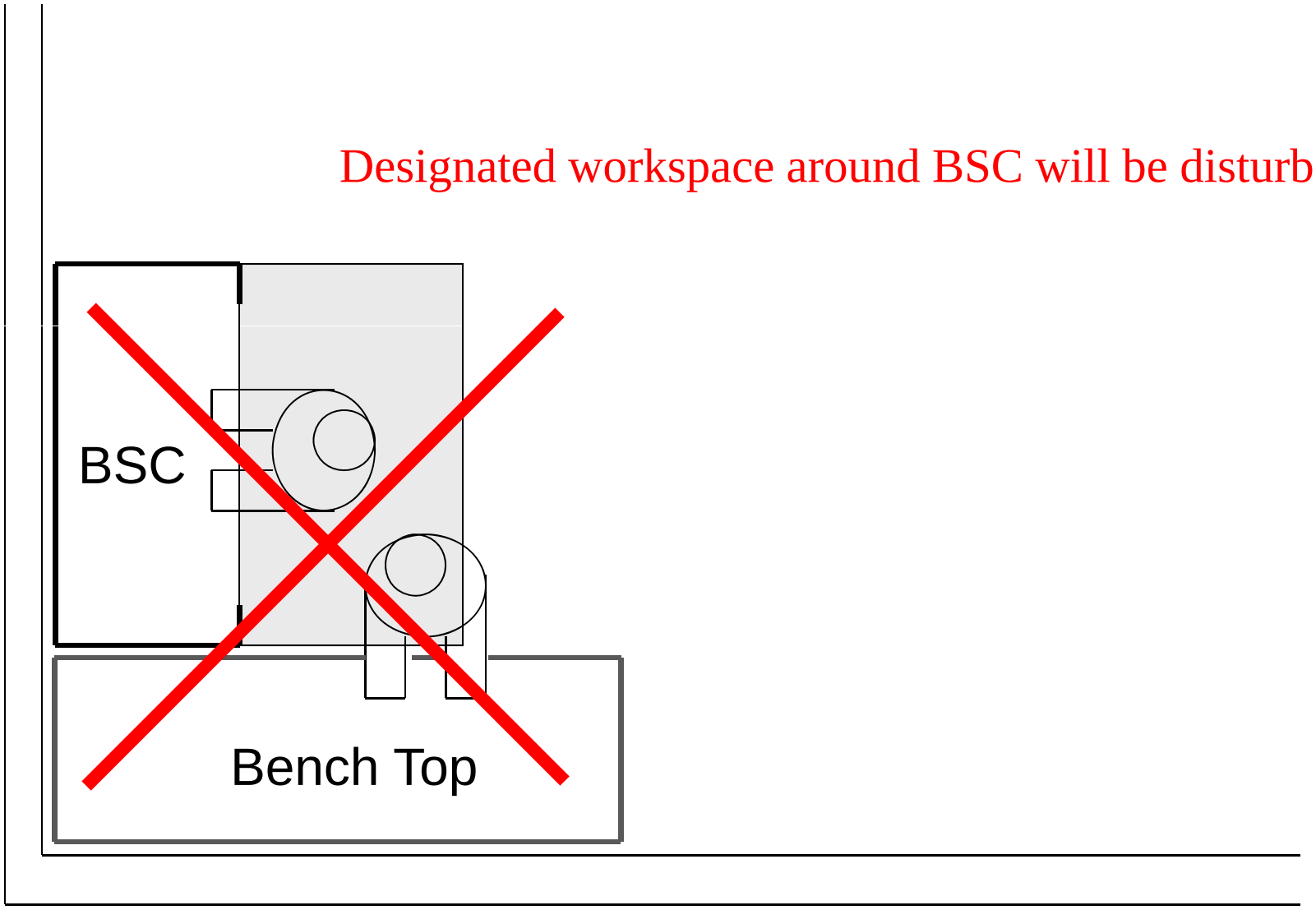
**DO NOT** Crowd together bench tops and BSCs.

Too much traffic produces dangerous disturbances to BSC airflow.



**DO NOT** Place BSCs directly near bench tops.

Designated workspace around BSC will be disturbed.



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