United States
Environmental Protection
Agency

Office of
Administration and
Resources Management (2304)

July 2004

EPA FACILITIES MANUAL, VOLUME 2

Architecture and Engineering Guidelines

Printed on Recycled Paper

Foreword

The *EPA Facilities Manual* is comprised of four distinct, yet complementary resources for planning and managing Environmental Protection Agency (EPA) facilities. These four volumes are meant to be used simultaneously to determine design intent, requirements, and the ongoing evaluation of all EPA facilities. The use of one volume without reference to the other three would result in an incomplete understanding of the requirements for EPA facilities.

Volume 1: The *Space Acquisition and Planning Guidelines* contain information on space planning, space estimation, environment, materials, furniture, process, and maintenance. EPA's Office of Administration and Resources Management developed this document to help EPA facilities managers, space managers, and line personnel plan and use their space.

Volume 2: *Architecture and Engineering Guidelines* (referred to as the *A&E Guidelines*) provide guidance for facilities management, engineering, planning, and architecture professionals in the design and construction of new EPA facilities and the evaluation of existing facilities.

Volume 3: The *Safety, Health, and Environmental Management Manual: Safety and Health Requirements* outlines safety and health considerations for owned or leased EPA facilities. The Manual's goal is to maintain a safe and healthful workplace that protects against injury, illness, and loss of life.

Volume 4: The *Safety, Health, and Environmental Management Manual*: *Environmental Management Guidelines*, establishes environmental specifications to be addressed by designers and managers of EPA facilities and related building systems.

Architecture and Engineering Guidelines

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Introduction

PURPOSE

The *Architecture and Engineering Guidelines* (hereafter referred to as either the *A&E Guidelines* or this Manual) are a compilation of standards and guidelines to be used in the design and construction of new Environmental Protection Agency (EPA) facilities (including additions and alterations) and the evaluation of existing facilities. This Manual shall be used in conjunction with the *Safety, Health, and Environmental Management Manual* (the *Safety Manual*) as the basis for the Program of Requirements (POR) and Solicitation for Offers (SFO). This Manual is also intended to be used, with the concurrence of EPA, to develop construction documents for public bidding and/or the award of construction contracts to meet relevant building code and EPA facilities requirements.

The primary purpose of this Manual is to establish a consistent, Agency-wide level of quality and excellence in the planning, design, and construction of all EPA facilities projects. It is not intended to deter use of more stringent or greater performance criteria for design. Project-specific design and construction requirements that are not in conflict with the requirements of this document should be met in developing the final program. The generic information and requirements described herein must be verified and further defined and refined.

USE OF THIS MANUAL

This Manual does not relieve the architects, engineers, and consultants of any of their responsibilities as design professionals. It is intended only to clarify and supplement existing codes and requirements to facilitate the design process for the design professional and the offeror. The architect, engineers, and consultants who will be involved in the design of an EPA-occupied laboratory, office, or storage facility shall be licensed professionals in their fields of expertise and shall be experienced in the design of such facilities. They will be required to ensure that all portions of the project comply with all established applicable codes, regulations, and practices for laboratory facilities, as well as with this Manual.

Citations of standards, codes, or references within this Manual should be assumed to refer to the most current edition. Years and publication dates specifically stated in the Manual reflect the version in use when the Manual was written and published. When using this Manual, the user should verify that the documents referenced are the most current and have not been superseded.

ORGANIZATION OF THE MANUAL

This document is generally organized according to the *Masterformat*, published by the Construction Specifications Institute (CSI). The 16-section format should be familiar to many in the fields of architecture, planning, engineering, and construction. When used throughout this Manual, the term “new construction” shall be understood to include additions and alterations to existing buildings.

The paragraphs in each section of this Manual are considered to be subsections and are identified by a hierarchical numbering system. When a paragraph is not numbered, it should be considered part of the preceding subsection. When subsections from this Manual are used in the project-specific manual, the subsections shall have the same numbers that they have in this Manual. Because the subsections of the project-specific manual are not renumbered, the project-specific manual can be directly compared and referenced to subsections in this generic Manual. When subsections from this Manual are not used, those numbers are omitted from the project-specific manual. As an alternative, the project-specific manual may contain all subsection numbers from this Manual, with the notation “this subsection not used” inserted after those numbers not included in the project-specific manual.

END OF INTRODUCTION

Section 1 - General Requirements

1.1 Overview

1.1.1 FACILITY DESIGN PROCESS

This section presents EPA generic space requirements, identifies the types of spaces anticipated for the various functions of an EPA facility, identifies general technical requirements, and gives general guidance for actual layout. The design professional must work in close coordination with EPA to produce the final building layout in accordance with this document and the guidance gained through consultation with EPA. Appropriate local, state, and federal regulatory agencies shall also be consulted.

1.1.2 DESIGN PRINCIPLES

The design of EPA facilities shall follow the following general principles:

- The design of any proposed EPA facility shall meet the specified program requirements while being functional and flexible—capable of keeping pace with the changes that are continually occurring in EPA programs.
- EPA facilities shall comply with the requirements of this Manual, relevant national, state and local codes, and GSA's Public Building Service guideline PBS-P100.
- The facility design must provide a high degree of energy efficiency and demonstrate sustainable design principles.

1.2 Pre-Design Process

The pre-design process for EPA facilities, including space acquisition and planning requirements, is generally discussed in Volume 1 of the EPA Facilities Manual. The pre-design process will generate various planning documents, studies, evaluations, and reports. The results and conclusions of these documents shall be properly addressed and incorporated into the facility design and construction phases of the project. The following considerations will be defined during the facility planning phase of the project and will be included in documents for guidance to the design professional.

- A brief overview and description of all existing facilities, and of the campus if the facilities are so composed.
- An overview of each component of the facility or campus
- A brief introductory description of the organization of the various branches and laboratories in the project and how they interrelate, and a more detailed description of each branch and laboratory
- A brief overview of the scope of the specific project requirements
- A brief description of the facility concept (i.e., number of floors, floor area, number of laboratories/special spaces, offices, location of site, acreage, characteristics)
- An environmental design intent document, which identifies the sustainable design goals and initial concepts. Gather typical meteorological year (TMY) data.
- A general description of the various facility spaces and area requirements to be utilized during the design of the facility and also the pertinent area requirements for the exterior areas of the project.
- Quantitative and qualitative requirements of the specific program and space identification and sizes
- Room data sheets for all facility spaces developed in accordance with the requirements of Volume 1, *Space Acquisition and Planning Guidelines* and Appendix C of this volume (for laboratories). The room data sheets must indicate specific room or laboratory requirements and identify appropriate installed equipment.
- Preliminary scope of work for the Commissioning Authority.

The design professional will be responsible for ensuring that the facility final design conforms to the specifications outlined in the planning phase documents and this Manual.

1.3 Design Submittals

The A-E shall submit required construction drawings, specifications, cost estimates, and design analyses/calculations to EPA-FMSD at interim stages of development. Not all projects will require submission at each of the stages indicated below; applicable submittals for each project shall be specifically indicated in the Solicitation for Offers (SFO) and/or Program of Requirements (POR). If submittals are found to be unacceptable at any stage, the A-E shall revise and resubmit them at no additional cost to EPA.

1.3.1 15 PERCENT SUBMITTAL

This schematic submittal stage is required on complex projects and/or where architectural design elements require coordination with interior design development or development of exterior design considerations. The 15% submittal ensures that the A-E demonstrate an understanding of the scope of the project and adherence to project criteria, formats, and conventions. At this stage, the A-E will submit, for example:

- Vicinity plan showing existing and new topography and utilities, access roads, extent of parking and site circulation, and relationships to other buildings
- Photographs of the site and surroundings.
- Single line floor plans showing all walls, openings, rooms and built-in features
- Facility organization plans and/or sections, showing main circulation paths and the locations of shared and specialized spaces.
- Building sections and typical wall sections showing floor-to-floor heights
- Exterior elevations showing fenestration and exterior building materials
- Space tabulation by room indicating net square footage, architectural treatment, and utilities
- Environmental design plan, including energy goals and strategy for achieving LEED™ Certification under the U.S. Green Building Council program (see 1.4.2.1).
- Energy model baseline simulations.
- Cost estimate reflecting the cost of the intended project and the cost of alternate schemes/solutions presented, including the cost for providing expansion contingency
- Code analysis, identifying all applicable codes and key criteria that will affect the design.
- Credentials of proposed Commissioning Authority.

1.3.2 35 PERCENT SUBMITTAL

The 35% submittal includes design development documents and supporting design calculations to clearly show the adequacy of project design and functional arrangements. This submittal includes, for example:

- Site development plans delineating all buildings in the area, proposed parking locations, roads, sidewalks, curbing, fencing, landscaping, storm drainage, and routing of water, sewer, gas, and other utilities
- Architectural plans showing complete functional layout, room designations, critical dimensions, all columns, and built-in equipment for each building section
- Analysis of LEED™ Certification potential, with checklist identifying the points to be sought and the strategies and steps necessary to achieve them. Energy-model report and recommendations.
- Life safety plans showing fire subdivisions and fire separation ratings throughout the building
- Preliminary furniture layouts for conference rooms, libraries, and similar spaces
- Mechanical plans delineating proposed layout of systems, location and preliminary arrangements of all major items of mechanical equipment, and basic outline of control system requirements (materials, methods, and sequence of operation)
- Plumbing plans showing proposed fixture locations and basic riser diagrams

- Electrical plans showing proposed electrical service and distribution array (preliminary one line diagram), lighting fixture patterns, and receptacle locations
- Preliminary riser diagram for communication and fire alarm systems
- List of applicable specifications for all materials, types of work, and architectural, structural, and mechanical systems
- Itemized cost estimates identifying all intended work
- Basis of Design Report
- Final scope of work for the Commissioning Authority.

1.3.3 60 PERCENT SUBMITTAL

The 60% submittal includes contract documents and supporting materials that clearly show the development of the project at the 60% stage. The objective is to provide EPA with sufficient drawings, cost estimates, and specifications to evaluate the A-E's adherence to detail and systems criteria, to review coordination between disciplines, and to ensure that comments made during previous reviews were understood and incorporated. The 60% submittal shall include, for example:

- Completed title sheet, drawing index, and legend sheets
- Detailed site and utility plans
- Detailed building floor plans with all walls, partitions, dimensions, door and window schedules and details, plumbing fixtures, and fixed equipment or items (e.g., fume hoods, sinks, cabinets)
- Composite floor plans (when applicable) showing construction phasing when required
- Developed roof plan and exterior elevations
- Developed finish schedule
- Updated LEED™ checklist, including preliminary calculations for points sought
- Completed fire protection/life safety plans
- Detailed calculation of heating and cooling loads, piping, ductwork, and equipment sizing associated with the HVAC system
- Detailed outline of control system requirements (materials, methods, and sequence of operation) and basic ladder diagrams and temperature control schematics indicating remote sensors, panel mounted controllers, and thermostats
- Detailed calculations for the sizing of the following plumbing systems: domestic hot and cold water, waste and vent, natural and liquified petroleum gases, vacuum, compressed air, distilled and deionized water, medical gases, and other specialty systems
- Detailed description of the fire suppression system and its controls, including activation, interlocks with HVAC system, and connection to detection and alarm systems
- Detailed description of electrical system design, including: lighting system(s), wiring system and location of proposed use, lighting protection system, grounding, basic characteristics of panelboards (including short circuit and voltage drop calculations), electrical metering, and electrical schedule
- Systems commissioning plan and preliminary commissioning specification
- Detailed cost estimate using quantity take-offs and unit prices.

1.3.4 95 PERCENT SUBMITTAL

The 95% submittal shall include contract documents and supporting material that can be considered biddable documents by EPA. This submittal includes, for example:

- Contract drawings and specifications that are 100% complete for all disciplines (architectural, structural, mechanical, electrical)
- Final calculations for all systems and equipment
- Final energy control system drawings, including the drawing index, control system legend, valve schedule, damper schedule, control system schematic and equipment schedule, sequence of operation and data terminal strip layout, control loop wiring diagrams, motor starter and relay wiring diagram, communication network and block diagram, and direct digital control (DDC) panel installation and block diagram

- List of proprietary items, long lead items and/or items that because of their uniqueness, critical tolerance in manufacture and/or installation, require particular scrutiny during construction
- Final architectural finish boards showing samples of proposed finishes
- Detailed cost estimate using quantity take-offs, unit prices, and labor costs. The cost estimate shall be sufficiently accurate at this stage that EPA can begin funding procedures.
- Draft LEED™ submittal, including all required information except that to be collected during construction

1.3.5 100 PERCENT SUBMITTAL

This submittal shall provide all final drawings, specifications, and cost estimates ready for contract award. With this submittal, the A-E shall also include an estimate of the time necessary to complete the project in calendar days and shall include manufacturer's catalog cuts and published data of major items specified and used as basis of the design.

1.4 Design Considerations

1.4.1 GENERAL

The facility should blend in with its natural and man-made environment. The building itself and all of its systems—architectural, mechanical, and electrical—shall be as flexible and adaptable as possible because functions and related laboratory operations often change. The proposed building(s) and systems shall allow for future space adjustments with minimal disruption to ongoing activities.

1.4.2 ENVIRONMENTAL DESIGN REQUIREMENTS

EPA facility design and construction must meet all requirements of EPA Facilities Manual, Volume 3, *Safety and Health Manual* and Volume 4, *Environmental Management Guidelines* and other environmental requirements of this volume. EPA facility design must also meet the requirements of Executive Order 13101, Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition; Executive Order 13123, Greening the Government Through Efficient Energy Management; Executive Order 13148, Greening the Government Through Leadership in Environmental Management; or any subsequent or superseding Executive Orders relating to the protection of the environment.

The architectural and engineering design of the facility shall use proven methods, strategies, and technologies exhibiting respect for, and protection of, the environment. These methods, strategies, and technologies include the use of nonhazardous recycled construction materials and construction materials produced with minimal expenditure of energy; and use of insulation, fire protection, and refrigeration systems that avoid use of chlorofluorocarbons (CFCs) and other ozone-depleting chemicals. The facility shall be designed to meet the requirements of the EPA Internal Pollution Prevention Program.

1.4.2.1 GREEN BUILDING CERTIFICATION

EPA is a recognized leader in energy conservation, pollution prevention and other sustainable building practices. As such, it is necessary to identify and incorporate these features in the design and construction of new and renovated facilities to the fullest extent possible. As one means of evaluating and measuring achievements in these areas, all EPA buildings must be certified through the Leadership in Energy and Environmental Design (LEED) Green Building Rating System (*TM) of the U.S. Green Building Council. Projects are encouraged to xceed basic LEED green building certification and to achieve the highest level of LEED certification available for each project undertaken. Specific achievement levels for each design and construction project will be indicated in the SFO and POR. For more information about this certification, please visit the following web site: http://www.usgbc.org/programs/leed.htm.

1.4.2.2 ENERGY-CONSCIOUS DESIGN

Fundamental design decisions related to energy conservation shall be made during the planning stages. New facilities shall meet energy efficiency standards set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE 90.1, 1999) and also shall be Energy Star certified. The building design and all construction features (materials and methods of installation, including mechanical and electrical systems) shall provide concepts that will reflect reduced energy consumption. The new design shall also utilize passive design techniques to minimize heating and cooling loads. These techniques include:

- Siting of facilities using prevailing wind and existing vegetation views (sun angle light and shading study).

- Efficient design of building form and envelope in response to climate

- Reducing cooling load and electrical lighting load through use of daylighting

  - The use of natural but controlled daylighting shall be maximized to the extent that it does not conflict with other EPA energy conservation objectives. EPA values natural light and considers it part of a good working environment. The building organization and design concept shall consider bringing natural light into personnel spaces.

  - Size, number, and location of windows shall be determined on the basis of need for natural light and ventilation and of other energy considerations. All windows in heated or air-conditioned spaces shall be double-glazed, insulated windows. Low E glass should be used for all exterior windows. Laboratory windows shall be fixed-pane, nonoperative windows. Use of operable windows in all non-laboratory function is encouraged. In an air-conditioned building where windows are operative, these windows must have a removable operating handle.

- Encouraging open plan concepts, with enclosed offices/rooms clustered and located off the windows, for HVAC efficiency and daylight penetration.

- Reducing solar heat gains through orientation and proper design of solar-shading devices combined with proper selection and location of building materials. Laboratory windows in particular are sensitive to solar gain and should be shaded on the exterior from direct rays with appropriate shading devices.

- Allowing occupant control of sunlight and glare at different times of the day/year through the use of interior shading devices such as light shelves, shades and/or blinds.

- HVAC systems designed for an integrated, energy-conserving facility.

All EPA buildings shall be designed to promote the use of natural light and to afford optimum use of energy-efficient lighting systems (e.g., electronic ballasts, task lighting). These include Energy Star lighting, light fixtures controlled by sensors, and other devices that save energy without jeopardizing safety or the light quality required for visual tasks.

1.4.2.3 CONSTRUCTION MATERIALS

EPA wishes to take a very active role in the selection of the materials used in the project and during the construction process. The design professional, in close coordination with EPA, shall carefully examine the environmental sensitivity of materials and products specified for construction and build-out for the new facility. EPA will encourage minimal use of products that are insensitive to the environment during and after manufacture and should consider local manufacturers (<500 miles) if available and cost effective. Construction materials shall have the highest practicable percentage of recovered materials as indicated in EPA's Comprehensive Procurement Guidelines (CPG). The specifications shall include environmental performance characteristics or other criteria to manage construction substitutions.

1.4.2.4 ELECTROMAGNETIC FIELDS

EPA seeks to limit the presence of electromagnetic fields (EMFs) in close proximity to people within the new facility. Prudent avoidance is required in the routing of electrical power. EPA recommends that the routing of power throughout the facility be well away from people and offices; for instance, elevator electrical chases and other electrical chases should be located away from offices and on exterior walls to the maximum extent feasible.

1.4.2.7 WATER CONSERVATION

EPA requires that the design of new facilities minimize water consumption through the use of water-saving measures. Facility design should follow the Federal Energy Management Program (FEMP) ten water efficiency improvement best management practices developed pursuant to E.O. 13123. The facility design should consider the use of low impact development and stormwater management strategies, including gray water recycling and xeroscaping, where feasible.

1.4.2.8 CONSTRUCTION PROTECTION

EPA recognizes that practices during the construction process can further the project's environmental goals, or compromise them. The design and the careful product selections must be protected during the construction period from damage, dirt, chemicals and moisture. To ensure good indoor air quality at occupancy, it is important that pollutants do not get into the building's air handling systems, which would circulate them throughout the finished space. In the specifications, the design professional will require the contractor to submit a construction protection plan that addresses the following:

- Preventing dust, dirt and smells from migrating into finished space from areas under construction
- Sealing ductwork and equipment until dust-producing activities are complete
- Keeping absorbent materials sealed or offsite until painting, adhesive application or similar activities are complete
- Using low-toxic cleaning supplies
- Collecting worker refuse (e.g., food, beverages)
- Preparing an erosion and sedimentation control plan that follows the practices in EPA's Storm Water Management for Construction Activities, Chapter 3 (EPA Document #EPA-832-R-92-005)
- Minimizing the disturbance to the site's natural features (e.g., trees, erosion control).

1.4.2.9 CONSTRUCTION AND DEMOLITION WASTE

Planning and on-site management can result in the reduction of construction waste generated, and the diversion of construction and demolition waste from landfills through salvage and recycling. With new construction and existing building renovations, the design professional will work will EPA to identify opportunities for reuse, salvage or recycling. Goals for recycling of construction and demolition waste will be incorporated into the contract documents. The facility design should incorporate waste prevention strategies, such as the use of modular components, designing to standard material sizes, considering prefabricated components, specifying mock-ups for tricky, repetitive details, planning for anticipated changes and material recycling of any construction/demolition waste (at a minimum: wood, metals, and paper).

The contractor shall recycle as much material as possible throughout all project phases. To accomplish this, the contractor shall: (1) submit a waste handling plan detailing how the waste stream will be separated and managed; and (2) provide onsite instruction on the appropriate separation, handling, recycling, salvage, reuse, and return methods to be used by all parties at the appropriate stages of the project. See <www.epa.gov/epaoswer/non-hw/debris/mgmt.htm> for more information.

1.4.3 EXPANSION AND FLEXIBILITY

Providing for future expansion and change is an integral part of the requirements for any new EPA project. The design professional shall review and/or confirm with EPA all anticipated expansion needs and shall recommend methods of accommodating expansion to meet these anticipated needs, as well as addressing future expansion beyond the anticipated needs. The design professional shall be responsible for recommending the direction(s) of expansion, after consultation with EPA. All expansion shall be accommodated in a logical manner, both programmatically and by construction sequencing.

- Corridor layout and circulation patterns shall enhance flexibility and aid in future expansion. Open plans, which allow greater flexibility in expansion and general facility changes, are encouraged where feasible, practical, and permitted by EPA.

- Floor plans that encircle a department with permanent corridors, stairs, mechanical and electrical rooms, or other fixed building elements that are difficult to relocate should be avoided. Column-free functional areas should be maximized, and use of transfer beams should be minimized.

- Anticipated expansion must be reviewed by representatives of all disciplines on the project.

- Expansion space shall be designed for each type of space used in the facility and for parking facilities. The design professional shall review the space requirements developed during the planning of the facility and identify areas that appear to be inadequately addressed for future expansion. Special attention should be given to the anticipated needs of technical or specialized space, because these are the most expensive to expand later.

- Electrical, mechanical, plumbing, and other support systems should be designed and sized to permit modification and expansion with the least cost and least disruption to overall operations.

- Design drawings that show existing building and site conditions along with proposed building and site designs are required to show both proposed building and expansion areas. All drawings shall be at the same scale. Enlarged studies of selected areas may be included. However, EPA desires a complete overview massing of the entire site for each proposed design, with expansion and flexibility clearly defined.

1.4.4 AESTHETICS

Aesthetics refers to the nature of both the interior and exterior of the facility. Aesthetic considerations should include, but shall not be limited to, the following:

- Contextual relationship of the adjacent buildings and environment. Color, texture, and massing of building components should be investigated. Historical and contextual details should be considered.

- The landscape design shall integrate site and building into one concept.

- The sequence of access, entry, and use of the building from the viewpoint of both staff and visitor must be considered.

- The interior finishes must be integrated into a single concept for the entire facility. This shall include all visible materials. Typical finishes, such as office/laboratory flooring and wall finishes, should be standardized to the extent practical, not only for consistency but also for maintenance efficiency and waste prevention.

- Consider accent and background colors, with special attention to their psychological effect on people.

- Special aesthetic consideration should be given to all building entrance lobby spaces

- Consideration shall be given to lighting from the view of both visual comfort and aesthetics. Visual comfort probability (VCP) for lighting fixtures should be a factor in selection. .

1.4.5 INTERACTION

Appropriate interaction space shall be incorporated where feasible. Design considerations to promote office group or researcher interaction shall include, but shall not be limited to, the following:

- Communication is a function of both organization and proximity. People communicate more if they work on a similar project or are in close proximity to each other. Research has shown that communication drops off dramatically after 30 meters (approximately 90 feet). It is desirable in laboratory facilities to cluster researchers in 30-meter-diameter groups, with shared facilities in between these research clusters. In office settings, a mixture of enclosed offices and open plan workstations in close proximity encourages group interaction and communication.

- Building form has an influence on communication. Whenever possible, personnel that need to communicate should be located in close proximity on the same floor. Research has shown that components of less than 10,000 square meters (108,000 square feet) should be located on one floor if possible.

- In laboratory facilities, the laboratory director shall be located strategically among his or her research staff. The director's office is best located toward the center of the facility. From an interaction perspective, a corner office with the best view is not the best location for the director's office.

- Offices arranged in a cluster may be a better form to promote communication and interaction than offices arranged in a linear configuration. Buildings that are arranged in odd shapes to provide all private offices with an outside window often compromise communication. Solutions that provide for both natural light and office clusters should be strongly considered. Additionally, clustering offices off the windows allows a better distribution of natural light, HVAC, and window access to those in workstations.

- When offices are put near laboratories, the researchers located in these offices have a greater sense of territoriality than if offices are farther away.

- Direct access should be provided to managers. Locating secretaries directly outside the manager's door often inhibits a subordinate from initiating informal contact with that manager.

- Library space appropriate to the laboratory/office functions should be located strategically to promote professional interaction and efficiency.

- Shared building facilities can be used as a tool to promote greater communication. Place the shared facilities to provide maximum intergroup communication. Shared building facilities should be located by proximity and in locations that enhance the users' ability to positively influence interaction.

1.4.6 AMENITIES

Amenities are spaces and/or features that provide an enjoyable environment for staff and visitors. A workplace that encourages communication, interaction, and collaboration among its users enhances worker productivity and increases employee retention. Strategic location of common support areas (i.e., conference rooms, restrooms, coffee and vending areas, clerical support services, and supplies) and carefully considered circulation patterns shall be incorporated to foster meaningful interaction. Building amenities must be dedicated, neutral spaces that are protected from encroachment and future conversion. An amenity exceeds the minimum functional requirements established by the program and may include the following:

- Interaction spaces, lounges, and break areas should be strategically located to foster maximum interaction while being convenient to both offices and laboratories.

- Conference and meeting room spaces appropriate to the laboratory/office functions should be provided in close proximity to the users. The meeting room spaces should be of various sizes and shapes to accommodate a wide range of conference needs. At least one of these conference rooms should be designed to accommodate teleconferencing and other audiovisual use.

- Lunchroom facilities should be sized specifically to each facility. Quality design of food service areas, concession areas, and seating areas with exterior views will contribute to an enhanced quality of life. It is also important to provide a place to safely consume food and drink outside of the laboratories, offices, and other work areas. Refrigerator space must be integrated into coffee and vending areas to eliminate the temptation to store lunches in refrigerators within the laboratories. Consideration should be given to appropriate microwave and oven appliances. A "white board" for impromptu conversations should be considered.

- In laboratory buildings, attempt to locate lockers and toilets close to laboratories and offices in such a manner that clothing and valuables are easily accessible to the staff. These facilities could be contiguous in most cases. Avoid placement of lockers in corridors. Where appropriate, the toilet/locker combination should accommodate a shower. The shower could satisfy staff after exercise and be used to stabilize a chemical accident victim prior to medical assistance.

- Space for an employee wellness center with appropriate facilities should be considered.

- Provide special attention to artwork and/or photos and how they are to be integrated into the design. The solution should include an integrated design for the display of EPA materials, which can be easily, quickly and inexpensively changed. This could accommodate research material in laboratory buildings, or ongoing EPA projects in other buildings.

- For reasons of safety, day or elder care facilities should not be included inside a laboratory facility.

1.4.7 HANDICAPPED ACCESS

The design and layout of an EPA facility must ensure that the facility is accessible to the physically challenged, in accordance with the Uniform Federal Accessibility Standards (UFAS) (1988) adopted by the GSA in 41 CFR Parts 101-19.6, the Americans with Disabilities Act (ADA), and all other applicable federal, state, and local laws and standards for buildings and facilities required to be accessible to and usable by physically challenged people (barrier-free design). Where different laws and standards are in conflict, the most stringent code shall apply. If there is difficulty in determining which code is most stringent, the Government reserves the right to make the final decision on the interpretation of all codes.

1.4.7.1 GENERAL ACCESSIBILITY

General access to the facility and any portion thereof shall be based on practical design and shall comply with all applicable standards, guidelines, and codes, including ADA and GSA 41 CFR Parts 101-19.6. Other aspects of general access are as follows:

- Avoid crossing pedestrian and vehicular circulation paths.

- Provide adequate circulation space at points of traffic congestion and provide architectural features that emphasize overall circulation patterns and major entrances.

- Avoid confusing corridor systems and extensions of through corridors from department to department.

- Avoid horseshoe-shaped major corridor systems that require excessive walking distances.
- Avoid dead-end departmental corridors.
- Minimize single-loaded corridors.
- Eliminate major corridors through elevator lobbies or through other areas that tend to concentrate circulation patterns.
- Locate vertical transportation so that it is visible from major entrances
- Provide clear directional signage for wayfinding, and departmental directories that can be changed easily.

1.4.7.2 LABORATORY ACCESSIBILITY

Accommodating the handicapped in a laboratory demands a design that is flexible, adaptable, and practical. The environment must function properly within handicapped regulatory requirements of the law and must offer safety for the users. Casework in all laboratories shall be capable of being modified to meet accessibility requirements at minimum cost. Some general criteria for handicapped accommodation in laboratories are as follows:

- The handicapped-accessible workstation shall provide a work surface that is 30 inches above the floor, with all wheelchair clearances below. Adjustable work surfaces that provide a range of height adjustments shall be considered for all such workstations.
- Utilities, equipment, and equipment controls for laboratory furniture should be within easy reach of persons who are physically handicapped and have limited mobility. Controls shall have single-action levers or blade handles for easy operation.
- Aisle widths and clearances shall be adequate for maneuvering of wheelchair-bound individuals. Aisle widths of 60 inches are required.
- Handicapped-accessible workstations shall be located as close to laboratory exits and safety showers as possible.

1.4.8 EXTERIOR BUILDING MATERIALS

The external treatment and materials utilized shall be of proven long-term durability and require minimum maintenance. The quality of materials shall be consistent with the image and dignity appropriate to a U.S. agency. Material selection should be based on an anticipated 100-year life cycle. In selecting building materials, careful consideration shall be given to all technical criteria as well as to the requirements and recommendations for recycled content contained in EPA's Comprehensive Procurement Guidelines (referred to hereafter as CPG) and Recovered Material Advisory Notices (see www.epa.gov/cpg).

1.4.8.1 EXTERIOR ELEMENTS

Mechanical, electrical, transportation, and equipment elements that are to be located on the exterior of the facility shall be integrated elements of the design. These elements include air intake and exhaust vents, exterior lights, utility connections, plumbing vents, fuel tank vents, liquid oxygen tanks, transformers, trash compactors, containers, loading docks, condensers, cooling towers, and mechanical equipment.

For laboratory buildings, mechanical equipment should not be located on roofs, due to vibration concerns, unless it is totally impractical to do otherwise. If mechanical or other equipment is located on the roof, particular attention must be paid to the vibration and to isolating such vibration inside the building. The equipment must also be aesthetically screened. Screening shall be designed to aesthetically hide the equipment and to prevent the entrance of rain into the fresh-air intakes of the facility and to prevent entrainment of laboratory exhaust air into the fresh-air intakes of the facility and adjacent facilities. Location of all exterior elements on EPA facilities shall meet the security guidelines in Section 1.8 and the requirements of Volume 3 of the *EPA Facilities Manual* (*Safety, Health, and Environmental Management Manual: Safety and Health Requirements*).

1.4.8.2 DESIGN CHARACTERISTICS

The design characteristics of wall schemes shall be evaluated in terms of aesthetics, function, and cost effectiveness with respect to the following:

- Moisture transport
- Thermal performance
- Aesthetic appropriateness
- Historic considerations (if applicable and appropriate)
- Durability (life cycle maintenance costs)
- Exterior wall termination at the roof or top of parapet walls (including penthouse)
- Construction and control joint locations, considering impact on construction sequence and building movement due to expansion and contraction
- Corner conditions, especially material relationships at the intersection 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
- Weathertight 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, daylighting, and life safety hardware.

Refer to Section 7, Thermal and Moisture Requirements, of this Manual for additional information on exterior building requirements in relation to thermal and moisture protection.

1.4.9 CONFINED SPACES

As much as possible, all areas with limited access or no ventilation shall be designed to ensure that the area is not and will not become a confined space as defined by 29 CFR §1910.146. Refer to the Safety Manual for ventilation requirements for storage rooms.

1.5 Structural Design Requirements

1.5.1 GENERAL

This section applies to the structural elements of buildings and other incidental structures. The structural elements include, but are not limited to, the following:

- All floor, roof, and wall framing members and slabs
- All piers, walls, columns, footings, piles, and similar elements of the substructure
- All other substructures and superstructure elements that are proportioned on the basis of stress, strength, and deflection requirements.

1.5.1.1 MATERIAL, FRAMING SYSTEMS, AND DETAILS

Material, framing systems, and details shall be compatible with the following:

- Clear space and span requirements
- Serviceability requirements
- Applicable fire protection classification, applicable local building code, and/or NFPA 220, as applicable
- Security requirements.
- Foundation conditions
- Future expansion requirements
- Architectural requirements
- Climatic conditions
- Structural design loads for the specific facility and location
- Site conditions
- Material reuse and recycling
- CPG requirements and recommendations, as appropriate.

1.5.1.2 CONSTRUCTION MATERIALS AND LABOR

Local availability of construction materials and labor force shall be considered in the selection of the structural system.

1.5.1.3 DESIGN CRITERIA

The structural design drawings shall indicate the design criteria; the structural materials and their strengths, with applicable material standards; the design loads, including loads that can occur during construction; and the allowable foundation loads that were used in the design.

1.5.2 CALCULATIONS

Calculations shall be prepared and presented as stated in the following paragraphs.

1.5.2.1 GENERAL

All design (including calculations) shall be performed and checked by a structural engineer registered within the project state. All calculations shall be on 8½-by-11-inch paper. Calculations shall be indexed and every page numbered. Dividers shall be placed between distinct sections. A summary shall be included describing the type of structure and indicating the live load capacity of each floor and roof.

1.5.2.2 MANUALLY PREPARED CALCULATIONS

Manually prepared calculations shall be neat and legible. Each sheet shall indicate the structural consultant's firm name, address, and telephone number. Each sheet shall indicate the designer's name or initials, the checker's name or initials, and the date prepared. Design assumptions regarding live loads, material strengths, conditions of fixity, etc., shall be clearly stated. Calculations shall be sufficiently cross-referenced that a third party can review the calculations without requiring additional information.

1.5.2.3 COMPUTER ANALYSIS AND DESIGN

Computer software used for structural analysis and design shall be from a nationally recognized vendor. Each separate run shall indicate software licensee, project name and number, engineer's name, and date. Additional manual annotation shall be provided, if necessary, to adequately cross-reference computer printouts, so that a third party can review the calculations without requiring additional information.

1.5.3 LOADS

Structures and their elements shall be designed for the loads prescribed in these criteria unless applicable codes or ordinances provide more stringent requirements. The most stringent requirement shall be used.

1.5.3.1 DEAD LOADS

Dead loads are loads that remain permanently in place. They shall include the weights of all permanent materials and equipment (including the structure's own weight) supported in, or on, a structure. Load calculations shall include an allowance for any loadings that are anticipated to be added at a later date. Initially assumed loads shall be revised so that the final design reflects the configuration shown on the drawings.

- The minimum allowance for the weights of partitions, where partitions are likely to be rearranged or relocated, shall be as follows:
  - For partition weights of 150 pounds per linear foot (plf) or less, an equivalent uniform dead load may be used, determined on the basis of the room dimensions (normal to the partition) and the partition weight in pounds per linear foot, but not less than 20 pounds per square foot (psf).
  - For partition weights above 150 plf, the actual loads shall be used.
  - Partitions that are likely to be rearranged or relocated should be calculated as live loads for load factor design. A factor of 1.1 shall be applied to the live loads due to movable partitions before application of building code–required live-load factors.
- The unit weights of materials and construction assemblies for buildings and other structures shall be those given in American Society of Civil Engineers (ASCE) Standard 7-02. Where unit weights are neither established in that standard nor determined by test or analysis, the weights shall be determined from data in the manufacturer's drawings or catalogs.
- Design dead loads shall include the weight of all permanent service equipment. Service equipment shall include plumbing stacks, piping, heating and air-conditioning equipment, electrical equipment, flues, fire sprinkler piping and valves, and similar fixed furnishings. The weight of service equipment that may be removed with change of occupancy of a given area shall be considered as live load.

1.5.3.2 LIVE LOADS

Live loads shall include all loads resulting from the occupancy and use of the structure whether acting vertically down, vertically up, or laterally. The weight of service equipment that may be removed with change of occupancy of a given area (e.g., fume hoods) shall be considered as live load. The design professional must secure any special requirements for floor loading from the Project Officer with the understanding that building codes, local codes, and agencies having jurisdiction regulate these requirements. Analysis in the early planning stages of a project is required to establish the loadings for specific pieces of equipment since these equipment loads may exceed the design floor loads. The timing and sequencing that the equipment is placed into the building must be considered; this will affect the design or construction phasing. The travel path of the equipment into the building must also be considered. The most stringent floor loading requirements shall govern. Operating, moving, stopping, and impact forces shall be considered part of the live loads. Live loads shall include neither dead loads nor loads from the environment, such as wind, tornado, earthquake, thermal forces, earth pressure, and fluid pressure.

- Live loads for buildings and other structures shall be those produced by the intended use or occupancy. In no case shall they be less than the minimum uniform load or concentrated load stipulated in ASCE Standard 7- 02, or required by the local building code, whichever is more stringent. A minimum of 60 psf of hanging load shall be included for any central energy plant or major mechanical room where significant hanging loads are anticipated.

- Live loads on roofs shall be as stipulated in ASCE Standard 7-02, or as required by local building codes, whichever is more stringent. Live loads on roofs shall include the minimum roof live loads or the snow loads and snow drifts or possible rain loads stipulated in the code, whichever produces the more severe effect. An allowance of 10 psf shall be included in the design of all roofs to allow for one re-roofing in the future. If a planted roof is being considered as a sustainable design feature, the load for the roofing system and retained water shall be included.

- In continuous framing and cantilever construction, the design shall consider live load on all spans, as well as arrangements of partial live load that will produce maximum stresses in the supporting members.

1.5.3.3 SNOW LOADS

Snow loads shall be as calculated in compliance with the provisions of ASCE Standard 7-02, or the requirements of local building codes, whichever is more stringent.

1.5.3.4 WIND LOADS

Wind load design for buildings and other structures shall be determined in accordance with the procedures in ASCE Standard 7-02, or local codes, whichever is more stringent, using site-specific basic wind speeds.

- Exposure “C,” as defined in ASCE Standard 7-02, shall be used as a minimum for all construction unless it can be shown that the necessary permanent shielding will be provided by natural terrain (not including shielding from trees or adjacent buildings).

- Building additions shall be designed as parts of a totally new building without regard to shielding from the original building and without regard to lesser wind resistance for which the original building may have been designed. The possibility that the original portion of the building may require strengthening because of an increase in the wind loads acting on it shall be considered.

1.5.3.5 SEISMIC LOADS

To comply with Executive Order 12699, Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction, the completed design for all new construction projects shall be submitted along with proper certification from a structural engineer registered in the state of performance that the design substantially meets or exceeds the seismic safety level in the current edition of the *National Earthquake Hazard Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*.

1.5.3.6 OTHER LOADS

Other load requirements are as follows:

1.5.3.6.1 EQUIPMENT SUPPORTS

Equipment supports shall be designed to avoid resonance resulting from the harmony between the natural frequency of the structure and the operating frequency of reciprocating or rotating equipment (e.g., fume hood exhaust fans, vacuum pumps) supported on the structure. The operating frequency of supported equipment shall be determined from manufacturers’ data before completion of structural design. Resonance shall be prevented by designing equipment isolation supports to reduce the dynamic transmission of the applied load to as low a level as can economically be achieved in the design.

1.5.3.6.2 FOUNDATION OR OTHER RETAINING STRUCTURES

Every foundation or other wall serving as a retaining structure shall be designed to resist, not only the vertical loads acting on it, but also the incident lateral earth pressures and surcharges, and the hydrostatic pressures corresponding to the maximum probable groundwater level.

1.5.3.6.3 RETAINING WALLS

Retaining walls shall be designed for the earth pressures and the potential groundwater levels producing the highest stresses and overturning moments. When a water-pressure-relief system is incorporated into the design, only earth pressures need be considered. In cohesive soils, the long-term consolidation effects on the stability of the walls shall be considered. Lateral earth pressures shall be determined in accordance with accepted structural and geotechnical engineering practice.

1.5.3.6.4 STRESSES AND MOVEMENTS

The design of structures shall include the effects of stresses and movements resulting from variations in temperature. The rise and fall in the temperature shall be determined for the localities in which the structures are to be built. Structures shall be designed for movements resulting from the maximum seasonal temperature change.

1.5.3.6.5 CREEP AND SHRINKAGE

Concrete and masonry structures shall be investigated for stresses and deformations induced by creep and shrinkage. For concrete and masonry structures, the minimum linear coefficient of shrinkage shall be assumed to be 0.0002 inch per inch, unless a detailed analysis indicates otherwise. The theoretical shrinkage displacement shall be computed as the product of the linear coefficient and the length of the member.

1.5.3.6.6 VIBRATION-SENSITIVE EQUIPMENT

The design professional shall be responsible for verifying the requirements of, and for, installation of vibration-sensitive equipment in all laboratory areas. The structural system in laboratory areas shall be designed to accommodate and control specific high localized frequency loads and vibration inputs from the general building systems to these sensitive areas. Five controls must be pursued:

- Use of physical separation to keep powerful sources of vibration well clear of the laboratory space.

- Identification and isolation of particular services that involve running speeds close to the natural frequencies of the floor.

- Identification and additional isolation of sources that, although they do not match the running speed of equipment and primary structural response frequencies, may produce sufficient vibration to cause a threat to the building.

- Identification, and, where possible, appropriate attenuation, of powerful transient impulses from services (e.g., switching in or out).

- Providing structural stiffness to reduce the peak acceleration responses caused by footfall-induced vibration.

1.5.3.7 LOAD COMBINATIONS

Combination of loads, allowable stresses, and strength requirements for buildings and incidental structures shall be as stipulated in the governing local building code.

1.5.4 STRUCTURAL SYSTEMS

The following paragraphs concern the basic supporting systems of buildings.

1.5.4.1 FOUNDATIONS

The provisions of the local governing building code shall be the minimum requirements for foundation design. The potential adverse effects of frost heave and movements due to expansive soils shall also be considered in the design. For all structures, the requirements of standard design criteria shall be met with respect to determining subsurface conditions, recommending foundation type, establishing allowable soil-bearing pressure, determining seismic potential, and differential settlement.

Where concrete slab-on-grade construction is used, the slab shall be placed on a capillary water barrier overlying a compacted subgrade. A moisture retardant shall be used under the slab, where moisture conditions warrant. Excess loads, or equipment subject to vibration, shall be supported by separate pads isolated from the rest of the floor slab with flexible joints.

1.5.4.2 FRAMING SYSTEMS

Buildings shall be framed to allow for simple formwork, fabrication, and construction procedures. Structural systems shall be designed for ductile modes of failure to the extent feasible.

In the selection of a framing system, consideration shall be given to the structure's functional requirements, including:

- Column-free areas
- Floor-to-ceiling heights
- Number of stories
- Elevator, escalator, crane, and hoist installations
- Heavy loads
- Other requirements pertaining to the specific facility.

For framed floors, the economy of prefabricated systems shall be considered, especially systems that simplify the installation of mechanical, electrical, and communications services.

1.5.4.3 LATERAL LOAD–RESISTING SYSTEMS

Lateral load–resisting systems shall be provided to resist the effects of wind, earthquake motions, thermal forces, soil pressures, and dynamic forces caused by rotating, reciprocating, or moving equipment. Use systems recognized by the local building code. In the absence of local building code criteria, use structural systems recognized by the International Building Code for use in resisting seismic loads.

1.5.5 BUILDING MOVEMENT JOINTS

Devices, usually in the form of joints, shall be designed into buildings to control movement.

1.5.5.1 CONTROL JOINTS

Control joints shall be provided in all materials subject to drying shrinkage. Control joint size and spacing shall be based on a rational analysis.

1.5.5.2 EXPANSION JOINTS

Expansion joints shall be provided in all materials subject to thermal expansion. Expansion joint size shall be based on a rational analysis. In the absence of local building code requirements, building expansion joints shall be provided as recommended in Technical Report No. 65 *Expansion Joints in Buildings* (National Academy of Sciences, 1974).

1.5.5.3 SEISMIC JOINTS

When seismic design is required, building expansion joints shall be seismic type. Buildings shall be separated adequately to prevent contact during an earthquake that would damage the structural systems of the buildings.

1.6 Architectural Requirements

Facility components shall be organized in a functional and aesthetic manner, according to a modular design concept that addresses the needs of all users of the facility. All administrative functions and all technical functions shall be grouped into separate organizational blocks of space while keeping them sufficiently close together to facilitate and encourage employee interaction.

EPA facilities are generally separated into three definable zones: laboratory (where applicable), administrative, and building support. This division allows not only the most flexibility for facility design but also the most cost effective construction. In reference to the interior space of a building or facility, the following definitions apply:

- Rooms and spaces refer to individual divisions of space, each one usually defined or enclosed by partitions or walls.

- Blocks are groups or series of rooms or spaces, usually having similar orientation and adjacencies.

- Zones are composed of two or more blocks of spaces, often providing the same or similar functionality.

The building design concept shall establish the appropriate horizontal and vertical alignments of the facility to facilitate required programmatic relationships. Multiple floor facilities with repetitive support areas should consider vertical stacking and clustering of similar functions and structural loading requirements to reduce costs, quantity of penetrations through floors, and system vulnerabilities. Floor plate areas shall be optimized to accommodate the required occupancies and to allow for future expansion or alterations.

1.6.1 LABORATORY ZONE

In research facilities, this zone includes all laboratories and laboratory support blocks within an individual branch or section. Laboratory-related office blocks shall be located in close proximity to related laboratories and laboratory support blocks. These offices shall be across from related laboratory space or in “clusters” along a laboratory-related corridor. Window exposure for both offices and laboratories should be maximized.

1.6.1.1 LABORATORY MODULES

The laboratory block(s) shall utilize a modular laboratory planning concept to maximize flexibility and adaptability of research space. The laboratory module represents the fundamental planning and organizing element. The repetitiveness and regularity of size, shape, and arrangement of space provides the ability to convert and renovate space quickly on the basis of each investigator’s unique set of laboratory design requirements and demands. As changes are required, the modular planning approach allows the expansion, subdivision, or reconfiguration of rooms without disturbing adjacent spaces or altering or forcing shutdown of, central building utility systems.

- The width of the laboratory module shall be at least 11 feet, from the centerline of the walls framing the laboratory module. The depth of a laboratory module should not be less than 26 feet or more than 33 feet. Within these limits, size shall be determined on the basis of task requirements and shall be consistent throughout a given block of laboratory rooms within a laboratory building. Laboratories with heavy instrumentation requirements may require the wider module due to equipment wire and service access. The design professional shall study the requirements, evaluate the equipment and instrumentation needed for each laboratory, and either use the planning module size or propose other module sizes that architecturally and operationally will provide the required features.

- The structural system shall allow for future changes in various mechanical and utility services. Floor-loading capability shall be uniform throughout the building to permit space usage conversions.

- Laboratory systems capacity must be determined on the basis of a common per-module denominator that anticipates future needs. In this determination, each module represents a unit of capacity for the building system (e.g., gallons of water, watts of power, cubic feet per minute [cfm] of supply and exhaust air). This generic method of calculating systems distribution ensures adequate building utility systems capacity and prevents costly shutdown and reconstruction of primary building systems components.

- Modular laboratory design shall integrate primary building systems (HVAC, piping, electrical power, and communications) into a distribution loop with modulated, consistent, recurring points of distribution relative to each planning module. These points of distribution give each module access to all laboratory systems; any additional services required in the future can easily be extended from the main distribution loop to the point of use. Each module shall have a readily accessible disconnect from each building system.

- Building systems must be readily accessible for maintenance and servicing. Components that require routine servicing should be located in corridor ceiling spaces or other spaces outside the laboratory perimeter. Servicing building systems components inside the laboratories is disruptive and difficult because of the amount of scientific equipment that must be protected. Whenever systems components are placed above ceilings, a lay-in type ceiling should be used, or access panels installed, to facilitate access for servicing and maintenance.

  - An important consideration for the laboratory design is the distribution of services on a modular basis within the laboratory. Special design attention shall be paid to location of structural members related to penetrations for services along the walls and near the benches located in the center of the laboratory.

1.6.1.2 LABORATORY SUPPORT BLOCK

Laboratory support space shall suit the needs of the specific laboratory. In some cases, a service corridor is used for laboratory support. In some cases, special support spaces are needed between laboratories. The laboratory support block is defined as the space that houses common, or shared, activities or equipment, such as analytical instrumentation, specialized equipment, environmental rooms, and glassware preparation areas, that indirectly support laboratory activities. These spaces can be interspersed between laboratories, supporting a specific activity, or can be grouped together adjacent to a block of laboratories. Particular attention shall be paid to functional relationships among laboratory support spaces and laboratories, with an emphasis on the efficiency of the travel path of personnel, tasks, and material within a particular zone and between zones.

1.6.1.3 TECHNICAL SPACE

Research support personnel (i.e., technicians, postdoctoral employees, laboratory assistants) should be provided with work space outside of the laboratory room in order to minimize long-term exposure to laboratory chemicals and the hazards presented by their use. Technician space, such as shared offices, alcoves, and cubicles, does not have to be directly outside of the laboratory as long as it can be placed reasonably close to the laboratory. Some desktop work space should also be provided in the laboratory for laboratory-related reporting and documentation that should not be done at the laboratory bench. These workstations, where provided, must be so located as to minimize exposure to noxious, or otherwise hazardous, conditions. The supply air and exhaust distribution system within the laboratory must be carefully coordinated with the designed work space to provide one or more "clean air" zones. In some instances, a physical separation, or barrier, may be required between the work space and the laboratory bench.

1.6.2 ADMINISTRATIVE ZONE

Administrative zones include office spaces and support service areas. The administrative offices shall be designed considering: circulation patterns of staff and staff interaction, visitors expected at the facility and their potential circulation patterns, and proximity of administration support functions, especially the resource center and meeting rooms, to administrative offices.

In laboratory buildings, the administrative zone should be physically separated from the laboratory zone in the same building. Building links between the administrative zone and the laboratory zone shall house pleasant and comfortable interaction spaces, such as a lounge.

Administrative support spaces include, but are not limited to, the spaces described below:

1.6.2.1 CONFERENCE ROOM

Conference room areas must be sized in proportion to the number of staff and conference activities anticipated. The proper and adequate design of conference space for administrative areas and research areas reduces travel time and promotes interaction. "Satellite conference rooms" can also double as "satellite resource centers" for periodicals related to special laboratory groups.

Conference areas that are centrally located for general administrative meetings are often designed to be subdivided with the use of folding sound-resistant doors. A vending area and related seating area may be coordinated adjacent to the main conference area to provide a broader use of the conference area. When conference areas and food-related areas are adjacent to one another, walls and doors must provide adequate sound control. CO_2 monitors should be considered for the HVAC control.

1.6.2.2 TELECONFERENCE ROOM

The teleconference room shall be designed to meet the specific teleconferencing needs of the facility. Additional issues to resolve include:

- Number of participants anticipated
- Special lighting requirements
- Special acoustic requirements
- CO_2 monitors should be considered for the HVAC control.
- Acoustic isolation from adjacent spaces
- Storage requirements
- Control room requirements
  - Determine whether a common control room for two conference rooms is required
  - Define control room requirements
  - Identify equipment requirements
  - Is a control room even required.

1.6.2.3 STORAGE

Storage areas adjacent to administrative offices are required to hold paper stock and miscellaneous equipment storage and for collecting old corrugated cardboard. Special attention shall be exercised regarding the need for storage space to hold extra supplies related to administrative conference space (e.g., tables, chairs, overhead projectors, slide projectors, and easels).

1.6.2.4 COPIER

Copier area shall be provided in close proximity to administrative areas. It shall be located to promote researchers/staff interaction. Area shall be enclosed and directly exhausted to the outside to provide adequate air quality. Adequate space adjacent to the copier is needed for proper storage, placement of mixed office paper and toner cartridge recycling bins, and collating or layout areas for sorting copies.

1.6.2.5 COFFEE/VENDING

A coffee/vending area shall be strategically located within a short travel distance from the area serviced. The coffee/vending area should be located to promote communication and researcher interaction. Adequate area shall be provided to accommodate separate bins for collecting newspapers and commingled bottles and cans for recycling. Often coffee/vending areas are co-located with concession purchased items. Special attention must be given to designing concession areas for both functional use and good aesthetic design. If there will be microwaves or other cooking appliances, the area shall be enclosed and exhausted directly to the outdoors for good indoor air quality.

1.6.2.6 COMPUTER ACCESS / PRINTER OUTPUT

Computer areas including computer staff offices, paper storage and computer tape storage are often designed into a "computer suite." Often, the "suite" will include printer output areas.

- The computer area shall be located as centrally as possible to reduce travel as well as wiring to computer terminals. The computer printer output areas are good interaction areas for staff and should be located to promote interaction.

- Special care is required to design both floor loading and fire ratings for film and paper storage areas. Special fire protection consideration is required for the computer areas. A preaction fire protection system shall be a part of the fire protection analysis for these areas.

- Computer areas will probably have access flooring that may require accessible ramps (ADA compliance required) to these areas. Special acoustical consideration is required in computer and printer output areas. If a glass wall is used to view into the computer area, adequate attention shall be given to fire protection of this glass wall.

- Adequate space adjacent to printers shall be allocated for placing bins for recycling mixed office paper and boxes for collecting used laser toner cartridges for recycling.

1.6.2.7 VISITOR INFORMATION CENTER

If the facility will be open to domestic and/or foreign visitors, a visitor center should be considered. A visitor center shall include, at a minimum, the following amenities:

- Relaxation area
- Projection/sound equipment
- Large screen television with video cassette recorder (VCR)
- Coffee area.

1.6.3 BUILDING SUPPORT ZONE

The building support zone design shall house a receiving dock, facility physical plant, mechanical equipment, and central storage. Its location shall be determined in accordance with the site master plan and should optimize service vehicle circulation. In laboratory facilities, the building support zone should be located adjacent to the laboratory zone to facilitate the movement of equipment and material to and from the laboratories.

Appropriate loading dock/staging facilities are required relative to the size, function, and material requirements of each laboratory. The truck turning radius to loading facilities should be appropriate to the truck size anticipated. The loading dock might include a leveling device for accommodating different size trucks. A covered loading/unloading area is desirable. The loading dock area shall be considered for video monitoring for security purposes. Issues to resolve are as follows:

- Nitrogen storage requirements and location; note security fence requirements
- Breakout area size
- Bulk mail process defined
- Access for emergency vehicle and ramps
- Truck parameters (dock height, leveler requirements)
- Security requirements
- Concrete paving for loading dock area
- Dumpster and compaction requirements
- Area for waste stream separation and recycling.

For laboratory facilities, an isolated hazardous materials/waste storage facility (HMSF) shall be also located near this zone to facilitate transportation and handling of explosive/flammable materials, toxic chemicals, and biohazardous waste before disposal at an off-site location by a licensed contractor.

1.7 Special Room/Space Requirements and Concerns

1.7.1 RESTROOMS

Each men's and women's restroom should have shower stalls and adequate lockers for the operation and the number of people, men and women, to encourage staff to bike or walk to work. Restrooms shall conform to ADA and/or UFAS requirements, as applicable. All sanitation finishes shall be non-permeable, non-corrosive, and easily maintainable. Restrooms shall be equipped with exhaust ventilation to the outside.

1.7.2 JANITOR CLOSETS/CUSTODIAL SPACE

Janitor closets shall be provided in sufficient numbers to service the various areas of the building(s). Each floor or block shall have at least one janitor closet with mop sink. These rooms shall be equipped with exhaust ventilation to atmosphere and louvered doors. Custodial space shall contain adequate storage space for cleaning equipment and supplies. Besides the custodial space located on each floor, a central custodial office, locker rooms and storage space shall be considered during the early phases of design. This area shall be located in close proximity to other building services areas.

1.7.3 SHOP FACILITIES

Shop facilities shall be located with exterior access appropriate to their function. The shop facilities shall be remotely located from vibration, noise, and dust-sensitive areas.

1.7.4 LIBRARY

The library shall be located with good access to storage, services elevator, and conference facilities. Additional issues are as follows:

- Type of library storage
- Computer terminals required
- Study carrels required
- Work space required
- Floor loading/structural requirements.

1.7.5 CHEMICAL STORAGE

Chemical storage shall be provided and be in compliance with the requirements of Chapter 4 of the *Safety Manual.*

1.7.6 GENERAL STORAGE

General storage is usually required on every floor. General storage facilities are the most typically forgotten or undersized spaces in EPA facilities. In Government facilities, where it is difficult to resolve equipment disposition, adequate storage space is critical. Additional issues to resolve:

- Locate storage internal to the building, maximizing underused space for occupied functions
- Ensure good access to service elevator
- Size rooms with freezers or other bulky equipment relative to equipment dimensions and layout
- Check corridor and elevator dimensions for movement of equipment
- Resolve signal runs to central control area as required by program
- Ensure space to collect corrugate cardboard for recycling.

1.7.7 FOOD SERVICE AND DINING

Food service must be located with good access to the loading dock and the service elevator. The food service and dining shall be as centrally located as possible with an exterior view if possible. Additional issues to resolve:

- Quantity of seating required
- Type of food service to be provided
- Secondary uses of food service spaces
- Placement of separate recycling bins for collecting newspaper and commingled bottles and cans.

1.7.8 OUTSIDE RESEARCH FACILITIES

Any outside research space related to a laboratory facility shall be constructed and designed to be of a quality that is in keeping with the research complex environment.

1.7.9 FIRE CONTROL ROOM

A fire control room is required inside high-rise buildings. In conjunction with local and EPA requirements, the local fire marshal shall be consulted to address and resolve any special concerns. Special attention shall also be provided to the elevator/service elevator design and its function in a fire fighting mode. Special consideration shall be given to the removal of fire victims from the building.

1.8 Security

1.8.1 ENTRANCE REQUIREMENTS

All entrances to the facility must be clearly defined. There shall be only one main entrance, although access to this main entrance may be from a variety of directions. The following are general design requirements for the main entrance:

- The main entrance shall be consistent with the design of the facility. The design of the space(s) and the material selection shall express EPA's and the facility's position in the world environmental community. Materials shall be high quality and durable.

- All entry spaces should be open, airy, and inviting to the entrant. All major entries should have vestibules and walk-off grilles to capture dirt, unless these are prohibited by historic preservation requirements.

- The main entrance must be easily recognizable and allow easy transition to other facility areas by first-time users of the facility.

- Each main entrance should be designed for incorporation of security equipment as defined in the POR. Security equipment may include card readers, x-ray equipment and metal detectors.

1.8.2 ACCESS AND EGRESS

The building subdivisions and the arrangement of exits, corridors, vestibules, lobbies, and rooms shall conform to requirements of the latest edition of NFPA 101, Life Safety Code, and/or local codes, whichever is most stringent, and shall allow fast and orderly exit in case of emergency and provide appropriate security for personnel, property, and experiments. The facility, buildings, and interior modules shall have controllable access, which should ensure a reasonably safe and secure working environment.

A security control station shall be at the main entrance, and security personnel shall have good visual control over the building's main entrance and lobby space, as well as monitor control over all other exits and entrances. Often a full-time security station is not economically justified by the amount of staff and visitor traffic through the main entrance of the facility. The receptionist may need to fulfill the security role. Administrative areas shall be in close proximity to the security control to provide reception function activities to support the security control staff.

1.8.3 EXTERIOR SPACES

The exterior spaces on the property shall be adequately secured to eliminate the potential of unauthorized individuals gaining access to the property. Potentially hazardous or accident prone exterior areas shall be secured by adequate perimeter security.

1.9 Quality Assurance/Quality Control

The design and construction contractor shall be responsible for quality control and shall establish and maintain an effective quality control system. The quality control system shall consist of plans, procedures, and organization necessary to produce an end product which complies with the contract requirements. The Contractor shall furnish for review by the Government, the Contractor Quality Control (CQC) Plan proposed to implement these requirements. The plan shall identify personnel, procedures, control, instructions, test, records, and forms to be used.

At a minimum the plan shall include:

- A description of the quality control organization, including a chart showing lines of authority.
- The name, qualifications (in resume format), duties, responsibilities, and authorities of each person assigned a CQC function.
- Procedures for scheduling, reviewing, certifying, and managing required samples, submittals, including those of subcontractors, off-site fabricators, suppliers, and purchasing agents.
- Control, verification, and acceptance testing procedures for each specific test to include the test name, specification paragraph requiring test, feature of work to be tested, and person responsible for each test.
- Procedures for tracking construction deficiencies from identification through acceptable corrective action. These procedures will establish verification that identified deficiencies have been corrected.

For construction contracts, the system shall cover all construction operations, both on-site and off-site, and shall be keyed to the proposed construction operations sequence. Construction will be permitted to begin only after acceptance of the CQC Plan or acceptance of an interim plan applicable to the particular feature of work to be started.

1.10 Commissioning Requirements

Refer to Appendix B of this Manual for the commissioning guidelines.

END OF SECTION 1

Section 2 - Site Work

2.1 Scope of Project

2.1.1 GENERAL

The location, type of building and support facility proposed, impact on site development, and general scope of work shall be described for the project. The description shall include such elements as access roads, parking areas, and loading and unloading areas, utilities, water supply, storm and wastewater.

2.1.2 DEVELOPMENT CODES

All site work must comply with the applicable federal, state, city, and local zoning and building codes and with the requirements of the Americans with Disabilities Act (ADA) and Uniform Federal Accessibility Standards (UFAS). Refer to Appendix A for some of the many codes, regulations, trade organizations, publications, and guides that may be applicable. When codes and/or regulations conflict, the most stringent standard shall govern. Information on applicable codes must be provided as stated in the following subsections.

2.1.2.1 ZONING

A brief overview of local zoning and land development codes and their impact on site development shall be given for the proposed project.

2.1.2.2 BUILDING CODES

Description of the applicable building codes shall be provided, with any specific references to seismic, floodplain, or coastal development as it relates to site development.

2.1.2.3 ADA REQUIREMENTS

The proposed project will comply with current federal (28 CFR Parts 35 and 36), state, and local ADA guidelines for the physically disabled.

2.2 Site Influences

2.2.1 LAND RESOURCES

Information shall be provided on the geography, geology, climate, typical meteorological data, and hydrology of the site areas.

2.2.1.1 SITE VICINITY

The geographic location of the project shall be described. Site location with respect to designated floodplains will be noted. EPA facilities shall not be located within the 100-year floodplain. Appropriate information on the local area economy, business, and industry shall also be provided.

2.2.1.2 PHYSIOGRAPHY AND GEOLOGY

A general description of known site geology and physiography shall be provided. Appropriate information shall be taken from the preliminary geotechnical investigation if this has been performed and is available when information is being gathered for this document. Seismic effects and the geological, foundation, and tsunami (seawave) hazards often associated with earthquakes must be considered. Probability with respect to severity and frequency of ground shaking varies from one geographic region to another; regions in which there are similar hazard factors are identified as seismic zones. Refer to the National Earthquake Hazards Reduction Program to determine the seismic zone in which the site is located.

2.2.1.3 CLIMATOLOGY

The specific climatic conditions of the proposed site shall be described, especially precipitation and predominant wind directions and highest expected wind gust on the site. Where available, local precipitation data shall be used in lieu of regional data for specific site hydrologic modeling.

2.2.1.4 HYDROLOGY

A general description of site hydrology shall be provided. This description shall include data taken from the preliminary geotechnical investigation and the Soil Conservation Service soil survey. The following specific site information shall be assembled for use in the hydrologic modeling of the project:

- Geographic location
- Precipitation frequency data
- Drainage area
- Soil and cover
- Runoff distribution
- Groundwater
- Rainfall intensity-duration curves based on historic record should be developed and used for each locale. The design storm events shall be based on a study of precipitation frequency, runoff potential, and runoff distribution relative to the physical characteristics of the watershed. Where available, stream gauge data shall be used to estimate design flows in major channels. Where stream gauge data are inadequate or unavailable, rainfall information shall be taken from documented sources, such as National Oceanic and Atmospheric Administration/U.S. Weather Bureau Technical Paper No. 40. Design storm precipitation values taken from documented sources or derived by published engineering methodology shall be used to estimate design flood discharges.

2.2.2 TRANSPORTATION SYSTEMS

The transportation requirements of the project and the project’s relationship to and effect on existing roadways shall be described.

2.2.2.1 AIR

A general description of project requirements for heliports or airfields shall be provided.

2.2.2.2 LAND

A general description of the proposed project and its location relative to existing roadways shall be provided. Development of the proposed facility and the impacts on the existing roadway system shall be addressed. This assessment shall include references to the traffic impact analysis if such an analysis is required for the project. For sites located in metropolitan areas with extensive public transportation systems, access to public transportation is desirable. A general description of proposed pedestrian and bicycle transportation systems should be included.

2.2.2.3 WATER

A general description of project requirements relative to boating shall be provided, including requirements for marinas, docking and/or storage facilities, seawalls and refueling facilities. Applicable permitting requirements of federal, state, and local agencies shall also be addressed.

2.2.3 ENVIRONMENTAL CONSIDERATIONS

The project’s effects on the surrounding environment, including air quality, water quality, and noise levels shall be addressed. Communities involved should be given the opportunity to participate in the identification of ways to reduce adverse environmental effects that negatively affect human health. A written Environmental Protection Plan for the construction effort shall be required.

2.2.3.1 AIR QUALITY

The impact of the proposed project on air quality shall be addressed. The assessment shall include all sources of air emissions and compliance with the requirements of federal, state, and local agencies.

2.2.3.2 WATER RESOURCES

The proposed project's impact on available water resources, including both ground and surface waters, shall be addressed.

2.2.3.3 NOISE POLLUTION

Any noise pollution that will be associated with the proposed project, its impact on surrounding development, and the project's compliance with applicable zoning and land development codes on noise pollution shall be addressed.

2.2.3.4 REDEVELOPMENT

EPA encourages building on previously developed land, rather than on undeveloped property. If brownfield sites are considered, remedial actions must be identified and resolved per EPA guidelines prior to construction.

2.3 Site Investigation

2.3.1 SITE SURVEYS

The design professional shall be responsible for providing site investigations, land (metes and bounds) surveys, and an environmental assessment of the site. Site investigations, land surveys, and environmental assessments shall be performed by professional engineers registered in the state of performance and/or land surveyors, as applicable.

At a minimum, the survey(s) shall show legal property boundaries, easements, and legal restrictions, as well as all man-made and natural physical characteristics, utility service locations (temporary and permanent), horizontal and vertical controls, benchmarks, roadways, and parking areas. Land surveys should conform to the requirements of General Services Administration (GSA) document PBS-P100 and the minimum standard detail requirements for ALTA/ACSM Land Title Surveys (1999), as applicable.

The degree of accuracy of construction, control, property, and topographic surveys shall be consistent with the nature and importance of each survey. Where required by law (i.e., applicable state statutes), all control and property surveys at EPA sites shall be performed by, or under the supervision of, a professional land surveyor registered in the state in which the site is situated.

2.3.1.1 PRELIMINARY SUBSURFACE EXPLORATION

Preliminary subsurface exploration shall be performed by a registered geotechnical engineer. The registered geotechnical engineer shall supervise all required testing, review and analyze all data and samples, and submit a report. All tests shall be performed by independent testing laboratories. Subsurface investigations should conform to the requirements of GSA document PBS-P100 Appendix A, as applicable.

2.3.1.2 ENVIRONMENTAL ASSESSMENT

Design and environmental professionals selected by EPA will evaluate the effects that the additions and improvements will have on the local environment. Under the purview of the National Environmental Policy Act (NEPA), an environmental assessment (EA) may also be required, which will determine the need for an environmental impact statement (EIS). The EA should conform to EPA environmental assessment requirements, as applicable. The preparation of the environmental assessment, if required, may be included as a part of the professional services contract. See also Chapter 9 of the *Environmental Management Guidelines (Volume 4 of the EPA Facilities Manual)*.

2.3.1.3 OUTDOOR POLLUTANT SOURCES

The facility shall meet the indoor air quality requirements described in Section 15 of this document. To address these requirements, the primary strategy for indoor air quality control is source control of outdoor pollutant sources. Effective source control requires that potential sources be clearly identified and addressed. The sources of air pollutants that must be considered are adjacent and nearby stationary pollution sources, for example, exhausts from other research facilities or from commercial buildings such as dry-cleaning establishments or restaurants, nearby roadways, parking lots, loading docks, trash storage, and garage and their motor vehicle traffic patterns. Consideration must be given to variations in the potential sources over time, including daily, weekly, and seasonal patterns. Temporal and spatial variations in wind direction and velocity, traffic patterns, and emissions from industrial processes that affect air quality at the site must be considered. The locations and forms of adjacent buildings that might result in local wind patterns causing reentrainment of the facility's own exhausts must be considered and addressed. The potential impact that ponds, cooling towers, cooling coil drip pans, and other potential sites of microbial contamination may have on IAQ must also be considered. Previous land uses, such as agriculture or industry, might result in emissions from contaminated soil or groundwater as a potential source of indoor air pollutants. Some examples of potentially significant prior uses are wood preservation and treatment; solid or hazardous waste handling, storage, treatment, or disposal; dry-cleaning processes; leather, paint, or chemical manufacturing; refrigerated storage; gasoline storage or dispensing; and agriculture. Even nearby building demolition can result in significant site contamination through release of building materials such as asbestos into air or into soil, which may remain on-site or be backfilled onto it. The design professional must include consideration of the following factors:

- Prior history of the site
- Off-site and on-site sources of pollution
- Soils and soil gases (including radon, organic chemicals, metals, and microbes)
- Ambient air quality
- Landscaping (including highly sporulating types of plantings).

2.3.2 SITE EVALUATION

The ultimate purpose of the site evaluation is to provide EPA with sufficient pertinent data to allow a complete evaluation of the physical conditions of the given project site.

2.3.2.1 SITE DATA COLLECTION

Using the information developed above and in other sources required by this document, the design professional shall consider planning and zoning criteria for the subject property. This consideration shall include the investigation of all potential site development regulations such as density limitations, building setbacks, building height, building coverage, buffer requirements, and other development guidelines set forth in any applicable campus, site, or facility master plan or elsewhere in this document.

An on-site investigation and review shall be conducted, which shall include representatives of the client, the design professional, and the preconstruction testing and inspection company. A site representative shall verify land features indicated on the survey. Photographs shall be taken at various locations to provide a visual record to aid in the development of the site analysis drawings.

2.3.2.2 SITE RESOURCE INVENTORY AND ANALYSIS

A site resource inventory and analysis shall be prepared, which shall include investigation of soil information, identification of site vegetation, hydrology and drainage analysis, topographic and elevation analysis, and analysis of view corridors and other physical characteristics of the site. A "buildable area" plan shall be developed by compiling information from the various analysis drawings. This plan shall indicate the acres of land that are suitable for construction. The site inventory and analysis shall include, but shall not be limited to, the following:

- The site overview will include, but will not be limited to, location, parcel delineation and acreage, existing zoning, and adjoining land uses.

- Physical site characteristic analyses include, but are not limited to, slope analysis, elevation analysis, existing vegetation identification, hydrology analysis, geological and soils analysis, site analysis, buildable areas analysis, wetland analysis, solar and shadow studies, and analysis of prevailing winds.

- Utilities include, but are not limited to, stormwater drainage, potable water, sanitary sewer, electrical power and communications, and mechanical systems.

2.3.3 GEOTECHNICAL INVESTIGATION

For permanent structures, subsurface conditions shall be determined by means of borings or other methods that adequately disclose soil and groundwater conditions. Data obtained from previous subsurface investigations shall be used, along with any additional investigations at the location that are deemed necessary. Subsurface investigations shall be performed under the direction of a licensed professional geotechnical engineer. Groundwater levels must be recorded when initially encountered and after they have been allowed to stabilize. In earthquake-prone areas, appropriate geological investigations shall be made to determine the contribution of the foundation (subsurface) to the earthquake loads imposed on the structure. These investigations shall include, but shall not be limited to, a recommendation of foundation type, determinations of allowable soil bearing capacity, and assessment of the possible effects of seismic activity on the soil mass. A settlement analysis under different design loads shall be performed where differential settlement may cause structural, architectural, or any other type of building damage.

2.3.3.1 TESTING AND SAMPLING METHODS

Testing and sampling shall comply with American Society for Testing and Materials (ASTM) standards, including ASTM D-1586, ASTM D-1587, and ASTM D-2113. Soil samples shall be taken below the existing grade and at each change in soil stratification or consistency. The depth of soil samples shall be determined by the geotechnical engineer after consultation with the project engineer on site-related design requirements.

2.3.3.2 TEST REPORTS

All data required by ASTM or the other standard test methods used shall be obtained, recorded in the field, and referenced to boring numbers. Soil shall be visually classified in the field logs in accordance with ASTM D-2488, but the classification for final logs shall be based on the field information, results of tests, and further inspection of samples in the laboratory by the geotechnical engineer preparing the report. At a minimum, the report shall:

- Include a chart illustrating the soil classification criteria and the terminology and symbols used in the boring logs.

- Identify the ASTM or other recognized standard sampling and test methods used.

- Provide a plot plan giving dimensioned locations of test borings.

- Provide vertical sections plotted showing (1) material encountered, (2) reference to known datum, (3) number of blows per linear foot (N value), and (4) groundwater level for all holes where groundwater is encountered. Data for groundwater shall include both the initial groundwater level and the static groundwater level.

- Note the location of strata containing organic materials, weak materials, or other inconsistencies that might affect engineering conclusions.

- Describe the existing surface conditions.

- Summarize the subsurface conditions.

- Provide pavement structural design data, including results of California bearing ratio tests or modulus of subgrade reaction tests.

- Provide a profile and/or topographic map of rock or other bearing stratum.

- Analyze the probable variations in elevations and movements of subsurface water due to seasonal influences.

- Report all laboratory determinations of soil properties, including shrinkage and expansion properties.

2.3.4 GROUNDWATER INVESTIGATION

A groundwater investigation shall be made before selection of a dewatering control system. The investigation shall examine the character of subsurface soils, groundwater conditions and quality, and the availability of an electric power source. The source of seepage shall be determined and the boundaries and seepage flow characteristics of geologic and soil formations at, and adjacent to, the site shall be analyzed in accordance with the mathematical, graphic, and electroanalogous methods discussed in Technical Manual 5-818-5, Dewatering and Groundwater Control (November 1983), U.S. Army Corp of Engineers. Field reports identifying groundwater elevations and other relevant features should be provided to the construction contractor responsible for dewatering and groundwater investigation.

2.4 Site Development

2.4.1 SURVEYING

The following surveys must be conducted, and the following survey documentation provided, for each site.

2.4.1.1 GENERAL

Construction, control, property, and topographic surveys shall be conducted in coordination with the appropriate EPA authority and the Project Architect/Engineer. Where feasible, surveying support available from EPA contractors shall be used. Survey field notes shall be legibly recorded on standard (8½-by-11-inch) field-note forms. Field notes and final plots of surveys shall be furnished to the appropriate EPA authority. Any boundary surveys and recorded maps shall be forwarded to the appropriate EPA authority.

The degree of accuracy of construction, control, property, and topographic surveys shall be consistent with the nature and importance of each survey. Surveys shall conform to the requirements of applicable local and state statutes), and shall be performed by, or under the supervision of, a professional land surveyor registered in the state in which the subject site is situated.

2.4.1.2 SURVEY CONTROL

The appropriate EPA authority shall be responsible for establishing, recording, and perpetuating primary on-site horizontal and vertical control monumentation. In addition, the appropriate EPA authority shall be responsible for correlating primary site-specific horizontal and vertical monumentation with that of other appropriate agencies. All surveying and mapping shall conform to the standards listed in Table 2.4.1.2, Survey Standards and/or state survey standards, whichever are more stringent.

Table 2.4.1.2 Survey Standards

Survey Standard	Survey Type
TEC-1110-1-147	CORPS Construction
ETL-1110-1-150	Global Positioning System (GPS)/Dredging
EM-1110-1-1000	Photogrammetry
EM-1110-1-1001	Geodetic control
EM-1110-1-1002	Monumentation
EM-1110-1-1003	GPS control
EM-1110-1-1005	Topographic and field supervision and maintenance [FY-94]
EM-1110-1-1006	Land boundary [FY-95]
EM-1110-2-1003	Hydrographic survey
EM-1110-1-1807	Computer-aided drafting design (CADD) (volumes 1-4)

2.4.1.3 MONUMENTATION

Requirements with respect to monumentation are as follows.

2.4.1.3.1 TEMPORARY CONTROL

For temporary control monuments:

- Where the scope and complexity of the project warrants, the placement, number, and location of temporary horizontal and vertical control monuments in new development areas shall be coordinated with the existing system and approved.

- A minimum of two intervisible control monuments shall be placed along, or adjacent to, right-of-way lines. These temporary control monuments shall be tied to an established grid. The surveyor who sets such monumentation shall submit legible notes, drawings, and reproducible documentation to the appropriate EPA authority. The location and construction of all temporary monuments in the immediate vicinity of new construction shall be indicated on the construction drawings.

- Temporary control monuments shall be 5/8-inch-diameter mild steel bars or 3/4-inch-diameter iron pipe with a minimum length of 2 feet or plastic hubs. These monuments shall be set flush with, or within 0.2 feet of, the ground surface. Manhole rims, markings chiseled in concrete, PK nails in asphalt, and lead and tack in bedrock shall be suitable as alternative temporary monumentation when approved.

- Three guard posts with reflective-paint striping shall be installed adjacent to temporary control monuments in high-traffic areas to prevent vehicular damage. Temporary control monuments shall be set in conformance with the accuracy standards of the U.S. Corps of Engineers.

2.4.1.3.2 PERMANENT CONTROL

For permanent control monuments:

- The placement, number, and location of permanent survey monuments for horizontal and vertical control shall be coordinated with, and approved by, the appropriate EPA authority.

The location and description of the nearest permanent survey monument shall be provided on construction drawings. These monuments shall be tied to an established state plane coordinate system.

- Any surveyor who sets a permanent survey monument shall submit legible notes, sketches, or other reproducible documentation that shows the location of the new monument relative to the on-site horizontal and vertical control network, to the applicable state plane coordinate system, to the North American Datum (NAD) of 1983, and to the National Geodetic Vertical Datum (NGVD) of 1929. The convergence, scale factor, and elevation on the monument shall also be shown.

- Permanent survey monuments shall be considered properly positioned and represented only after the appropriate EPA authority has approved all survey procedures and calculations and has verified conformance to the Corps of Engineers standards and specifications.

- Permanent survey monuments shall be identified as prescribed by Corps of Engineers standards.

- These identification numbers shall be documented within the survey field notes and shown on the design drawings and within related documents. Temporary point identification for permanent survey monuments may be assigned by the surveyor; however, permanent point identification shall only be assigned to such monuments by the appropriate EPA authority. Permanent survey monuments shall not be removed without prior authorization from the appropriate EPA authority.

2.4.1.3.3 BENCHMARKS

For benchmarks:

- A minimum of one permanent benchmark for vertical control shall be established in each new development area. A minimum of three benchmarks shall be established if there are no existing benchmarks within a 3-mile radius of each new development area. Elevations shall be referenced to the North American Vertical Datum (NAVD) of 1983 or to the NGVD of 1929. Level section misclosures between fixed benchmark elevations shall equal or exceed third-order accuracy, as defined in the Federal Geodetic Control Committee (FGCC) Standards and Specifications for Geodetic Control Networks.

- Permanent benchmarks shall be identified in the same manner as permanent survey monuments. Permanent benchmarks shall not be removed without prior approval by the appropriate EPA authority. The location and description of all benchmarks in the immediate vicinity of new construction shall be indicated on the construction drawings.

2.4.1.3.4 UTILITY, ROADWAY, AND PARKING AREA SURVEYS

Surveys of utilities, roadways, and parking areas shall be conducted according to the following requirements:

- Coordinates and elevations shall be determined for utilities, roads, and parking areas at their principal points of definition. This information shall be provided on the construction drawings. The principal points of definition for utility systems shall be utility poles, obstructions, manholes, valve boxes, culverts, and other appurtenances for heating and cooling lines, sewers, and overhead and underground power and telephone systems.

- Principal points of definition for potable water, and natural gas, distribution systems shall be valve boxes, main line intersects, elbows, and fire hydrants.

- The principal points of definition for roads shall be roadway centerline intersects. Road alignment surveys shall include stationing, bearings, and curve information tied to these principal points of definition. Where applicable, the following information shall also be provided on the construction drawings:

  - Stations and deflection angles for each point of intersection.
  - Right-of-way lines and markers.
  - Spot elevations (centerline, edge of pavement, and at intersects) at maximum intervals of 100 feet.
  - Other improvements (e.g., drainage inlets, wheelchair ramps, fire hydrants, sidewalks, and curb and gutter).
  - Topographic features within project limits.
  - Elevation contours.
  - Overhead and underground utility crossings (plan and profile).
  - Roadway drainage crossings.
  - Location and description of underground utility witness markers.

2.4.1.3.5 UNDERGROUND UTILITIES

Where exact routes of underground utilities are not defined within record drawings, the appropriate EPA authority shall coordinate necessary electronic line detection and exploratory excavation activities. Such utilities shall be located by survey and documented on the construction drawings.

2.4.1.3.6 CONSTRUCTION STAKING

Construction staking for new EPA facilities shall comply with local standards and with practices approved by the appropriate EPA authority.

2.4.2 SITE PLANNING AND DESIGN

In the development of a site proposed for construction, it is necessary, at a minimum, to address, analyze, and assess all site-related issues outlined below and to comply with the requirements of Chapter 2, Site Planning and Landscape Design, GSA document PBS-P100, as applicable.

2.4.2.1 IMPACT

The following issues are to be studied in assessing the impact of a project on a given site or the man-made or natural environment:

- On-site capacities of present and future utilities

- Existing buildings (discussion shall include any need for temporary facilities and services to these buildings)

- Existing site utilities (discussion shall include any need for utility relocation and shutdown)

- Stormwater run-off, wastewater discharge (including acid wastewater)

- Existing traffic patterns and vehicles, including emergency and service vehicles

- Availability and proximity of public transportation

- Need for traffic phasing and control-plan requirements

- Existing parking structures and surface parking (discussion shall include any need for temporary parking areas and additional capacity)

- Exhaust discharge
- Energy usage (e.g., building placement/orientation, sun and shadow, analysis of prevailing wind patterns)
- Need for an environmental impact statement.

2.4.2.2 DEVELOPMENT

The following issues must be taken into account in determining whether the proposed development is appropriate and compatible with its natural environment and surrounding community.

- Preserving surrounding neighborhoods and communities. Laboratory facilities shall be located in areas where local zoning permits; however, facilities should be no less than one-quarter mile from existing residential developments and shall be located in such a way that prevailing winds will not direct fumes exhausting from EPA stacks toward existing residential developments.
- Preserving the character of the site, to the maximum possible extent, by retaining natural features, such as ground forms, trees, and other natural vegetation.
- Using the existing site to best advantage by locating and orienting buildings so that they are compatible with natural site features.
- Developing functional relationships between site access points, parking lots, buildings, service areas, and all other project site elements.
- Providing for orderly future expansion of facilities by considering logical expansion of buildings, parking, and support services.
- Reviewing and assessing the impact of development with respect to any approved campus master plan and site infrastructure master plan.

2.4.2.3 DESIGN CONSIDERATIONS

The following issues must be considered in planning any EPA facility or site.

2.4.2.3.1 ENERGY CONSIDERATIONS

Sun angles, light and shadow studies, prevailing winds, existing topography, microclimatic conditions, and major wooded areas shall be carefully analyzed to contribute to a more energy-efficient solution. Energy conservation should be enhanced by careful consideration and evaluation of the orientation of buildings. Climate assets should be maximized and climate liabilities minimized

2.4.2.3.2 VIEWS

Proper orientation of facilities to capitalize on major vistas is strongly encouraged. Views into the site from major roadways should be carefully designed to be attractive and reflective of EPA's mission.

2.4.2.3.3 TOPOGRAPHY AND DRAINAGE

A design shall be provided that works with, and not against, the existing grades. Significant positive drainage away from any existing or new construction is a primary concern. The design shall preserve, as much as is practical, any major existing drainage patterns.

- The natural grades of the site should be used to develop multilevel entry points, if possible. Positive drainage away from all portions of the building is required.

- The location of the 100-year floodplain shall be determined, and if this is present on the site, the boundaries should be delineated on all surveys and site plans.

- The impact of development on stormwater runoff must be assessed, including absorption and retention..

2.4.2.3.4 ADJACENT LAND USE

In siting a facility, consideration should be given to existing land uses or potential development nearby, because such land use may affect or restrict the facility design. Existing and proposed traffic patterns shall be considered in the design of site access and driveway locations.

2.4.2.3.5 NOISE, FUMES, AND ODORS

Adjacent land uses may contribute noise, fumes, and odors; these uses shall be considered in the site development process. Noise or odors may be severe enough to disqualify a site from consideration; therefore, a thorough analysis of neighboring facilities must be undertaken to ensure compatibility of the proposed facility with the existing adjacent land uses and environment.

2.4.2.3.6 VIBRATION

If there are adjacent land uses that produce vibrations that can be measured on a proposed site, the extent of the vibration and whether it will affect the proposed program shall be determined.

2.4.2.4 HISTORICAL AND ARCHAEOLOGICAL CONSIDERATIONS

All applicable publicly available documents shall be reviewed for any on-site historical or archaeological information. Any public record indicating historically or archaeologically sensitive areas on-site must be reported to EPA before any design is initiated. Archaeologically and historically sensitive areas on-site must be completely avoided until, and after, a thorough investigation has been completed and findings documented that provide direction on whether the area(s) in question may be used or must be preserved for future exploration.

2.4.2.5 COMMUNITY ISSUES AND ENVIRONMENTAL JUSTICE

Environmental justice issues, as established by EPA, shall be addressed and the requirements of any required community review processes ascertained. A report shall be provided to EPA early in the design process and well before any community review is required on the project. All community reviews are over and above any EPA design review; reviews shall not be combined. Requirements of community review panels may include, but are not limited to, the following:

- Separate plans prepared to specifically highlight or emphasize that group's concern.

- Research and data collection to be used in generating special reports and in the environmental assessment.

- Presentation graphics for a formal submission or presentation during the review process.

- Documentation of the review and approval process, submission requirements, deadlines for each portion of the process, and the sequence that must be followed.

- Identification of the methodologies, research, and data needed to identify and evaluate populations at disproportionately high environmental or human health risks and to ensure that these needs are considered in developing any EPA facility.

2.4.3 FACILITY SITING

This subsection addresses facility siting issues and requirements.

2.4.3.1 GENERAL

A site development plan shall be used to locate new facilities on existing or new sites in order to ensure effective site utilization and avoid future conflicts between existing and new facilities.

- During facility siting, an environmental assessment shall be prepared before the initiation of a Government action that may significantly affect the environment.

- To the extent possible, facilities shall not be sited in floodplains or in areas subject to flash floods; facility siting shall minimize destruction, loss, or degradation of wetlands.

- In selecting the particular site on an acquired or predetermined campus style site for new facilities, the conditions and requirements of Section 3.2.2 of the Space Acquisition and Planning Guidelines and the following shall be considered:

  - Programmatic and operating efficiency.
  - Endemic plant and animal species.
  - Past use of site and existence of known Resource Conservation and Recovery Act (RCRA) and/or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites.
  - Health, safety, and environmental protection requirements.
  - Indoor air quality impacts (e.g., presence of radon in foundation soils and contamination from other exterior sources, natural or man-made).
  - Hazardous operations and consequences of potential accidents in adjacent facilities.
  - Wave action within any natural or man-made body of water (in accordance with the Coastal Engineering Research Center [CERC] Shore Protection Manual).
  - Energy conservation requirements.

2.4.3.2 LABORATORY SITING

New laboratories, EPA owned and leased, should be sited in consideration of the following guidance.

- Guidance from *Criteria for Siting of Laboratory Facilities Based on Safety and Environmental Factors,* prepared for EPA by Johns Hopkins University, School of Hygiene and Public Health, Peter S. J. Lees and Morton Corn.

- Site acquisition methodology as prescribed in the Environmental Closure Process for EPA Laboratories chapter of the Safety, Health and Environmental Management Program Guidelines.

- Local zoning code.

- Indoor air quality criteria referenced in Chapter 5 of the *Safety Manual*.

- Location shall be large enough to accommodate the laboratory building and outbuildings (hazardous materials building) with adequate setbacks meeting local requirements and RCRA requirements.

- Laboratories preferably shall be located in light industrial areas where there are provisions for containing accidental spills prior to discharge to the local stormwater system and in areas that have fully staffed emergency response personnel (fire and medical), including hazardous materials (HAZMAT) teams.

- Laboratories shall not be located in residential areas or in mixed-occupancy high rise locations.

2.4.3.3 BUILDING LOCATION

New buildings and building additions shall be located in accordance with the site development plan.

2.4.3.3.1 OPEN SPACE

Open space shall be provided between structures to accommodate site security, landscaping, and other environmental considerations. Sufficient access shall be provided around building exteriors to accommodate emergency vehicles, maintenance vehicles, and snow removal equipment. In cold climates, building entrances, stairs, and other pedestrian circulation features should not be placed along the north side of buildings or within shaded areas. Off-site drainage areas and the environmental impacts that proposed stormwater management practices will have on surrounding properties shall also be carefully reviewed.

2.4.3.3.2 CONDITIONS AND REQUIREMENTS

The following conditions and requirements shall be considered during site selection for new buildings:

- Architectural and functional compatibility with the environment
- Operation and service function relationships
- Natural and humanistic orientation and wayfinding
- Natural topographic and geologic conditions
- Existing cultural and archaeological resources
- Historic sites
- Abandoned mines or wells and potential for subsidence
- Endemic plant and animal species
- Availability of existing utility services
- Building setback requirements
- Availability of existing road systems and public transportation
- Traffic volume
- Refuse handling and loading zone requirements
- Adequacy for parking, future expansion, and other land use requirements
- Health, safety, and environmental protection requirements
- Physical protection requirements
- Security and safeguard requirements
- Energy conservation requirements
- Indoor air quality impacts (e.g., presence of radon in foundation soils)
- Impact of site selection
- Minimum fire separation between buildings (in accordance with National Fire Protection Association [NFPA] 80A)
- Utilities.

2.4.3.4 HAZARD SEGREGATION

In general, occupancies posing different levels of risk shall be separated by fire-resistive construction. Areas shall be segregated as noted below and as required by local building codes and NFPA 101.

2.4.3.4.1 PARKING STRUCTURES

The construction, protection, and control of hazards in parking structures shall comply with the requirements of NFPA 88A. Parking garages located within buildings that contain other occupancies shall be separated from the remainder of the building by construction that has a fire resistance of at least 2 hours. Entrances between garages and elevators shall be protected by a vestibule having a 1½-hour, Class B or higher fire door. Doorways between garages and stairs, building corridors, or other non-garage areas shall be protected by 1½-hour, Class B or higher fire doors. The garage ventilation system must be designed as a separate entity from the main building and from the occupied spaces, with the exhaust from the garage directed outside. No recirculation of air is allowed in garages. In garages located under buildings, elevator vestibules shall be positively pressurized to prevent garage vapors from entering the occupied areas.

2.4.3.5 BUFFER ZONES

The buffer zone between the EPA facility and other existing or potential sites for building(s) shall be no less than 100 feet. Hazardous materials storage facilities (HMSF) shall be at least 50 feet away from any building or potential sites for building(s). Both the main facility and the HMSF shall be located at least 50 feet away from the property line. Existing highways and streets can be part of the 100-foot buffer zone. Paved parking area(s) for vehicles can be considered as part of the building buffer zone.

2.4.4 SITE PREPARATION

Local topography shall be considered during project and facility design. New facilities shall be planned to fit the local topography and to require a minimum amount of grading. Design shall include provisions for erosion control and soil stabilization in ditches, fill slopes, embankments, and denuded areas, and restoration of areas disturbed by the project. Restoration shall be to original or improved conditions.

2.4.4.1 DESIGN CONSIDERATIONS

Site preparation design shall meet the following criteria:

- Vehicle parking, sidewalks, and road requirements shall comply with subsection 2.6 of this Manual
- Site drainage design shall comply with subsection 2.7 of this Manual
- Site power and lighting shall comply with Section 16, Electrical Requirements, of this Manual.
- Site security requirements shall be taken into account and provided for in accordance with criteria established by the appropriate EPA authority.

2.4.5 DEWATERING

The design, installation, and operation of dewatering systems for groundwater control shall be the responsibility of the construction contractor, unless otherwise stipulated in the contract. The groundwater investigation and the selection and design of a dewatering control system shall comply with TM 5-818-5 and consider recharge beds and retention basins. The design engineer shall determine whether the assistance of a qualified groundwater hydrologist shall be required.

2.4.6 SHORING AND UNDERPINNING

All shoring and underpinning shall comply with the safety requirements of CFR Part 1926, Subpart P. Remedial underpinning shall be performed where existing foundations are inadequate. Precautionary underpinning shall be performed where new construction adjacent to an existing structure requires deeper excavation. A structural engineer specializing in underpinning shall perform any underpinning design, which shall comply with the principles in Winterkorn and Fang, *Foundation Engineering Handbook*.

2.4.7 EARTHWORK

Earthwork includes excavation, filling, stabilizing, and compaction of earth at the site. Earthwork also includes the addition of borrow and the disposal of excavated material. The earthwork design shall incorporate the findings of the geotechnical report required by subsection 2.3.3 of this Manual.

2.4.8 WATERFRONT CONSTRUCTION

Waterfront construction includes seawalls, docks, marinas, and other ancillary boating facilities associated with coastal development. This type of construction for EPA facilities shall comply with applicable federal, state, and local standards and with practices approved by the appropriate EPA authority.

2.5 Landscaping and Site-Related Requirements

2.5.1 GENERAL

Landscape planning, design, and development must be integrated with building massing, design, and materials. The landscaping design process must coincide with the building design process to create a single design that integrates site and buildings(s). The use of durable exterior materials that enhance both the site landscaping and the building design and help to integrate the two design disciplines is strongly encouraged.

If the facility is to be a part of an existing campus or among other buildings in a master-planned development, the landscape design as well as the building design must be integrated and compatible with the style(s) of the previously constructed permanent facilities on campus. The existing physical features of the site and surrounding buildings shall be observed and documented.

- The landscaping of the site shall create an environmentally sensitive and aesthetically attractive design. The natural environment should blend with the proposed new construction.

- Landscaped courts and open spaces that are accessible to all staff are encouraged.

- Grass-covered areas away from public view shall be provided and equipped as outside eating and visiting areas (with picnic tables, benches, and landscape furnishings).

- The facility surroundings shall be landscaped with trees, shrubs, flowering plants, and grass in a way that will enhance the aesthetic character of the building(s) and hide or screen exposed equipment and building parts, features, or functions that, by their nature, are not aesthetically pleasant. Vegetation may be used to screen, or form a barrier to, particulate matter and to protect the building(s) from motor vehicle pollutant sources.

- Using trees and vegetation to shade large hardscape areas, such as parking lots and summer sun building exposures, is encouraged.

- The topography of the site around the building(s) shall slope away from the building(s) and away from neighboring building(s) to direct any water away from the new facility and from any neighboring building(s).

- Xeriscape design practices (use of sustainable local/regional vegetation requiring minimal watering) shall be used to minimize maintenance of the plantings. Use of irrigated turf grass in new landscape design shall be prohibited.

- In general, low-maintenance landscape design and features shall be used. High efficiency irrigation, and/or the use of captured rainwater is encouraged where irrigation is necessary.

- Energy efficient exterior lighting with low-voltage or solar powered is encouraged.

2.5.2 PROFESSIONAL QUALIFICATIONS FOR SITE DESIGN

All site landscaping shall be designed by a state-registered landscape architect. This landscape architect must maintain his or her registration continuously and without break for at least the entire design and construction process and for the life of the design contract for the project.

- All site landscaping shall be installed and/or modified by a professional landscaper or professional gardener. All landscaping (plants and grass), except for annuals, if used, shall be guaranteed for 16 months after acceptance by EPA.

- All costs for the landscaping shall be anticipated in the final cost estimate. These costs shall be included in the overall costs of the project. Such costs shall include, but shall not be limited to, the following:

  - Retaining curbs and walls
  - Plantings and grasses
  - Exterior signage and graphics
  - Site furniture and furnishings
  - Irrigation
  - Site hardscape and special pavings
  - Warranties and guarantees
  - Exterior screens and barriers
  - Specialty features incorporated into the design
  - Maintenance guarantees
  - Site lighting
  - Site sculpture.

2.5.3 GENERAL SITE REQUIREMENTS

All landscaping and site amenities for the proposed development shall be in accordance with all applicable local, state, and federal codes and industry standards. Also, landscaping and site amenities shall comply with any master plan or campus design requirements and all construction requirements and standards. The more stringent requirements shall be used if a conflict exists.

2.5.3.1 EXISTING CONDITIONS

The landscape architect shall (1) preserve existing trees and undergrowth, where appropriate, for buffers; (2) review buffer requirements of the local community; and (3) use existing trees to the extent possible, since the larger size will provide greater immediate impact on-site.

2.5.3.2 PLANTINGS

Guidelines on plantings are as follows:

- Establish functional design criteria.
- Consider focal or entry area; design main entry area to produce an obvious sense of arrival at facility
- Create views or screen views as needed.
- Develop color and seasonal interest.
- Provide orientation (e.g., with respect to sun and wind) for facility and creation of shade.
- Consider ultimate size and scale relative to specific area or site size.
- Consider site-appropriate formal planting plan or informal, naturalistic plan.
- Avoid major plantings in areas where expansion is planned.
- Provide appropriate location of plantings relative to prevailing wind and sun.
- Break up large areas of pavement with landscape islands.
- Choose local/regional plants and design plantings to be tolerant of climate, weather conditions, rainfall, and other environmental conditions.
- Determine irrigation requirements.
- Determine maintenance requirements such as fertilization rates, soil acidity, and, if required, pruning and trimming needs.
- Coordinate plantings with location of signs, light standards, hydrants, underground utilities, and other man-made structures.
- Ensure that lawns slope to provide proper drainage (minimum 1 percent grade).
- Provide ground cover on severe slopes for aesthetic and maintenance considerations.

- Planting must be reviewed and approved by the appropriate EPA personnel. The landscaping plan shall identify the names, caliper sizes, and number of trees, shrubs, and all other plantings in the plan.

2.5.3.3 SITE FURNITURE AND FURNISHINGS

Guidelines for choosing and locating site furniture and furnishings are as follows:

- Select furniture design to complement the building theme
- Use materials with recycled content as designated in the CPG, with an emphasis on sustainability and longevity
- Determine quantity and location of furniture
- Establish function intended for seating and waiting areas, outdoor meeting areas, and eating areas
- Determine flag pole heights, location, and quantity and integrate into the design
- Locate fences and identify their style, color, and purpose
- Integrate trash and recycling receptacles, cigarette urns, newspaper dispenser boxes, and mailboxes into the design
- Include safety review of proposed surfaces, equipment, and layout of programmed recreational and playground equipment.

2.5.3.4 SITE LIGHTING

The following guidelines apply to site lighting:

- Design lighting to complement the architectural and land planning theme and to accord with any current master plan or campus requirements.

- Utilize energy-efficient and easily maintainable fixture types (the selection of lighting fixtures must consider long-term costs).

- Heights of lighting standards must be appropriate to the scale of the building and the area being lit.

- Provide lighting intensity that is commensurate with the use of the area and the health and safety of employees and other persons accessing the building during non-daylight hours.

- Control light with respect to adjacent property and to minimize glare, striving for zero direct beam illumination leaving the building site.

2.5.3.5 EXTERIOR SIGNAGE AND GRAPHICS

Considerations with respect to exterior signage are:

- Appropriate scale
- Viewing angle and speed of observer
- Appropriate color and letter style and clarity of message
- Appropriate locations for signage, including intersections, parking lots, and entries
- Design that complements the building style, accent color, or building color
- Clear identification of functions: traffic direction, orientation, and general information
- Coordination of building identification at site entries with that on the buildings themselves; identification should be strong, legible, and compatible with interior signage and graphics
- Compliance with signage ordinances (such compliance is required)
- Providing special identification for the project, if required
- Signage must be reviewed and approved by appropriate EPA personnel
- Designing exterior signage to allow future removal and change without damage to existing exterior materials and to allow possible reuse of the signage after its removal and/or reuse of the lettering of the removed signage.

2.5.3.6 OUTSIDE SERVICE AND UTILITY AREAS

Many elements are necessary for the proper operation of a building. Some are visually undesirable and require proper planning for screening and buffering, which should be incorporated into the building design. The design professional is responsible for coordinating the work of all disciplines and for identifying all elements of the proposed project that will have a visual impact. The following are among the items that may require appropriate screening and buffering:

- Meters
- Vaults
- Transformers
- Dumpsters
- Recycling containers
- Compactor units
- Emergency generators
- High pressure gas cylinder storage and manifold systems
- Pressure reducers
- Valves
- Pump hoses
- Outdoor storage areas
- Loading docks
- Mechanical equipment
- Compressors and cooling towers.

2.5.4 HARDSCAPE REQUIREMENTS

Hardscape (paving) and hardscape materials shall be integrated with the building and architectural planning and with landscaping design and concept. In general, materials that soften typical hardscape (paving) designs shall be used. Light colored, high albedo, hardscape materials shall be considered to reduce the absorption and radiation of heat. Use of porous pavement materials is encouraged where feasible. Appropriate material usage shall be integrated with an understanding of project budget and public versus restricted access and use areas.

2.5.5 RECREATIONAL REQUIREMENTS

Recreational site requirements shall be reviewed with EPA on a project-by-project basis.

2.5.6 IRRIGATION

Water efficient irrigation methods, such as drip irrigation systems and low-flow bubblers, shall be utilized where supplemental moisture is required. All irrigation systems shall be equipped with automatic controllers that activate the system according to a desired frequency and duration, and shall be equipped with rain or soil moisture sensors that will prevent irrigation during periods of rainfall or when there is sufficient moisture in the ground for plant health and survival. Use of reclaimed water and/or stormwater for landscape irrigation is acceptable and encouraged.

2.6 Vehicle and Pedestrian Movement

2.6.1 ACCESS AND CIRCULATION

Although visual and other aesthetic aspects of access to the project site, and thus to the project facilities, are critical, the primary access requirements involve fire and life safety. The most current version of the *Safety Manual* shall be reviewed for these guidelines. Either traffic data will be provided or a traffic impact analysis will be performed. Geometric design of all roads, streets, access drives, and parking areas shall comply with American Association of State Highway and Transportation Officials (AASHTO) GDHS-84. Gradients for roads, streets, and access drives also shall comply with AASHTO GDHS-84. Road and street grade changes in excess of 1 percent shall be accomplished by means of vertical curves. The length of vertical curves shall be determined in accordance with AASHTO GDHS-84. Roadway centerline gradient profiles shall be shown for vertical control.

- Design and details of construction of flexible and rigid pavements shall comply with the local state highway department standards. Concrete valley gutters may be provided if swales with flexible pavements are necessary. Joint layout plans and details shall be provided for all rigid pavements. A thickened edge shall be used along edges of rigid pavement where future construction will occur.

- Design should promote logical wayfinding.

- Signs, pavement markings, channelization, and other traffic control measures shall comply with the requirements of the U.S. Department of Transportation (DOT) *Manual of Uniform Traffic Control Devices*.

2.6.1.1 FIRE DEPARTMENT APPARATUS ACCESS

Fire department access involves fire department apparatus and on-site fixed fire safety equipment (e.g., fire hydrants, fire loops, fire pumps, post-indicator valves, automatic sprinkler and standpipe system connections), vehicular circulation, pedestrian circulation, and parking. Local codes, ordinances and fire department requirements must be reviewed to provide adequate access. The following minimum requirements shall be met:

- All new buildings shall have at least two sides readily accessible to fire department apparatus at all times.

- Fire lanes shall be provided for buildings that are set back more than 150 feet from a road or that exceed 30 feet in height and are set back more than 50 feet from a road.

- Fire lanes shall be at least 20 feet wide, and the road edge closest to the building shall be at least 10 feet from the building.

- The minimum roadway turning radius shall conform to a 48-foot semitrailer template.

- Fire lanes shall be constructed of an all-weather driving surface capable of supporting imposed loads of 25 tons. If appropriate for the area and climate, these lanes may consist of compacted earth with top soil and seed.

- Any dead-end road more than 300 feet long shall be provided with a turnaround at the closed end of at least 90 feet in diameter.

- Fire lanes and access areas for fire hydrants and automatic sprinkler or standpipe connections shall be clearly identified by painting the curbs yellow, with black lettering reading “NO PARKING - FIRE LANE” spaced at 40-foot intervals. In addition, signage carrying the same message shall be posted at 100-foot intervals along the restricted area.

2.6.1.2 VEHICULAR CIRCULATION

Vehicular circulation design shall comply with the following requirements and guidelines:

- Vehicular circulation shall be designed in accordance with code requirements and any overall campus master plan or facilities master plan philosophy in effect at the subject site. Circulation shall respect the pedestrian circulation environment of the campus and/or facilities and provide for safe movement of vehicles and pedestrians. Existing traffic studies shall be evaluated and coordinated in order to implement the best possible overall circulation system.

- Vehicular access to a new project shall be evaluated with respect to existing and planned site circulation and shall provide for clear separation of staff, visitor, service, and bus vehicular circulation.

- Adequate emergency vehicle access shall be provided to all points on the building periphery by use of proper grades, surface materials, clearances, and other design features.

- Entrances to the facility or campus shall be clearly marked and located so that access to each building, parking area, group of buildings, and service area is convenient and recognizable.

- The siting of new buildings shall take into account the requirements of future expansion, design of buildings, roads, and surface and structured parking.

- Site vehicular design shall provide adequate space for queuing at drop-offs and exit drives for visitors, buses, 18-wheel vehicles, taxis, and other vehicle types, keeping turning conflicts to a minimum and permitting proper service vehicle maneuvering and staging.

- Internal drive aisle widths and turning radii shall be designed to allow for the expected service and emergency vehicles.

- Loop circulation is encouraged to minimize site traffic backup.

2.6.2 PARKING AND LOADING FACILITIES

Parking areas should not be located in front of buildings or at visually prominent locations along routes of approach. Landscaping, grading, and location shall emphasize attractive features and de-emphasize or obscure undesirable features. Parking and its related circulation shall be separated from the service circulation to minimize conflicts. Parking lots shall meet local governmental standards for circulation, layout, and safety. Handicapped parking allocations shall comply with ADA guidelines. Perimeter concrete curbs and gutters shall be considered for all parking areas and access drives in built-up areas. In remote or little-used areas, concrete curbs and gutters shall be used only when required to control drainage. Removable prefabricated concrete wheel stops may be used where appropriate. Specific parking design guidelines are presented in the following subsection.

2.6.2.1 PARKING DESIGN

Parking for the proposed development shall be based on applicable codes for occupancy, local zoning requirements, and any campus or facility master plan in effect at the subject site. If the parking required by codes falls under 25 cars per 10,000 gross square feet of the facility, a more detailed analysis shall be made to verify that adequate parking is provided. If local codes require more parking spaces, the more stringent requirements shall apply. As part of the site development phase, multilevel parking garages or below-ground parking shall be considered as an alternative to surface parking. At a minimum, the following guidelines shall be followed:

- Distribution of total parking (e.g., employee [by type], police, emergency vehicle, visitor, handicapped, motorcycle, bicycle) shall be calculated and clearly shown in the site development phase. The minimum size for standard passenger car stalls shall be 9 feet × 19 feet. Up to 15 percent of the parking may be designated for compact cars. Stalls for compact cars shall be at least 8 feet × 18 feet. Car-pool policies should be considered in the calculation (and given preferential locations.)

- The structural design for pavement on surface lots shall comply with local state highway department standards for general parking areas.

- Parking aisles and lots subject to frequent truck traffic shall be evaluated to determine whether thicker pavement sections are required.

- Design calculations shall provide for a potential growth in staff of 10 percent. Provision shall also be made for expansion of the facility, with the design for future parking expansion shown.

- Alternate fuel refueling station should be considered on a facility-by-facility basis.

- Parking areas must be clearly related to entry points. Walking distances should be kept to a minimum.

- Handicapped parking spaces shall be provided in accordance with ADA requirements or the requirements of state codes and ordinances if these are more restrictive.

- Sufficient slope (1 percent minimum) shall be provided for positive drainage for runoff. Slopes shall be no more than 4 percent.

- Sufficient open lawn area shall be allowed adjacent to parking lots for snow storage, as required by climate and area.

- Wherever possible, 90-degree parking design should be used.

- Porous paving and/or recharge beds under parking should be considered, retaining the maximum amount of on-site storm drainage.

- Surface drainage in parking areas must not cross designated pedestrian paths.

- Dead-end parking bays are not allowed.

- Existing large trees should be integrated into new parking areas, where feasible.

- Except in remote or little-used areas, parking areas should provide curbs (consistent with site design) with a minimum 2-foot overhang behind the curb.

2.6.2.2 BICYCLE FACILITIES

Convenient bicycle parking facilities shall be included at all facilities, except those in remote areas. Suitable means for securing the bikes must be provided, sheltered/covered areas are encouraged. The capacity should be based on local conditions but a minimum capacity of 5% of the buildings's occupants is suggested, which is commensurate with LEED™ requirements.

2.6.3 PEDESTRIAN ACCESS

A functional system of walks connecting structures, operational areas, parking areas, streets, and other access paths shall be provided to meet the demands of pedestrian traffic. The location and width of these areas and paths shall be determined in accordance with the site development plan. Walks subject to use by the physically disabled shall comply with current ADA guidelines. Specific guidelines for the design of pedestrian walkways are prescribed in the following subsection.

2.6.3.1 DESIGN OF PEDESTRIAN WALKWAYS

Pedestrian circulation shall be designed in accordance with industry standards, code requirements, and any overall campus master plan philosophy in effect at the subject site.

- Pedestrian walks shall have a minimum of 1 percent cross pitch for drainage.

- The width of walks shall be a function of pedestrian traffic volumes determined by the master plan and/or by specific project requirements.

- Walks shall accommodate handicapped persons. Slopes, landings, and access points shall be in accordance with ADA requirements as well as with the most stringent applicable code or combination of codes applicable to the project.

- Crosswalks from parking, bus stops, and other buildings shall be clearly painted and properly assigned.

- Walkway paths shall be designed in response to the expected-origin/destination analysis of the site and its users.

- Drop curbs shall be used to provide transition for handicapped persons at crosswalks, drop-off zones, and ends of walkways.

2.6.4 AIRPORTS AND HELIPORTS

This subsection provides general guidelines for design of aviation facilities and indicates requirements and conditions that must be considered in designing and assessing such facilities.

2.6.4.1 GENERAL

Planning and design of aviation facilities and airspace clearances shall comply with Federal Aviation Administration (FAA) AC 150/5050-5. Planning and design of aviation facilities shall emphasize safety for all modes of aircraft operations. Aircraft installations require permanent unobstructed airspace, and facilities and equipment constructed to facilitate maintenance, ground handling, and flight operations.

- Landing and takeoff paths (traffic patterns) shall be oriented to avoid need for critical-facility overflights. Traffic patterns and altitudes shall be established and published to provide for aircraft approaches that are away from critical facilities.

- Heliports shall be sited, and traffic patterns established, so that normal operation does not require overflights of critical facilities. Heliports shall not be located closer to critical facilities than 2 times the dimension of the landing pad or 3 times the rotor diameter of the largest helicopter authorized to land at the heliport.

2.6.4.2 SITE CONSIDERATIONS

The following site conditions shall be taken into account in determining the adequacy of the aviation facility:

- Topography
- Vegetation and existing construction
- Weather elements
- Prevailing wind direction in summer and winter
- Soil conditions
- Flood hazards
- Natural and man-made obstructions
- Adjacent land uses
- Availability of usable airspace
- Accessibility of usable roads
- Location of site utilities
- Accommodation of future expansion
- Aboveground utilities.

2.6.4.3 DESIGN CONSIDERATIONS

The layout of airfield facilities shall support operational efficiency and provide safe conditions for takeoff and landing operations and for ground handling of aircraft.

- Airfield safety clearances shall comply with the clearance criteria of FAA AC 150/5300. The critical-decision-point and emergency landing areas for the various aircraft using a facility shall be determined on the basis of the respective aircraft performance charts.

- All other applicable design elements shall conform to the most current FAA criteria.

- In accordance with FAA AC 150/5070-6A, airfield layout shall also consider:

  - Wind direction and velocity analyzed
  - A taxiway system
  - Parking aprons
  - Supporting facilities.

2.7 Stormwater Management

2.7.1 STREET DRAINAGE

Street drainage in developed areas shall be conveyed within the roadway cross section. Curb inlets shall be used to divert storm flows to surface and subsurface stormwater conveyance systems. Curb inlets shall not be located within curb returns or in areas of heavy pedestrian traffic. Pedestrian and cyclist safety shall be considered during selection of storm inlet grates. Curb gaps shall be used where roadside drainage swales exist. Wherever possible, curb openings with inlets located in grassed areas should be utilized in lieu of curb inlets.

In locations where uninterrupted vehicular access is essential to critical operational activities, roadway cross sections shall be designed to convey runoff from the 25-year, 6-hour storm so that one driving lane width (12 feet) is free of flowing or standing water. Lower classification roadways shall be designed to convey runoff from the 10-year, 6-hour storm. Stormwater management systems shall have sufficient capacity to ensure that runoff from the 100-year, 6-hour design storm will not exceed a depth of 10½ inches at any point within the street right-of-way or extend more than 2½ inches above the top of the curb in urban streets. Inverted crown roadway cross sections shall not be used unless approved by EPA.

2.7.2 WATERSHED DEVELOPMENT

Site development plans shall be developed with careful review of the impact the plan will have on the watershed. Appropriate stormwater management strategies shall be developed to minimize or eliminate adverse effects on existing and future development within the watershed.

2.7.3 EROSION AND SEDIMENTATION CONTROL

Erosion and sedimentation control measures, in accordance with federal, state, and local standards, shall be used during construction. The site should be properly graded and planted to minimize erosion.

2.7.4 STORMWATER RETENTION AND DETENTION

Site development plans shall incorporate appropriate stormwater retention/detention facilities into the storm drainage system. These facilities must be designed in strict accordance with all applicable federal, state, and local requirements. Consider a further decrease in the rate and quantity of storm water run-off as an environmental design strategy.

2.7.4.1 ROOF RECOVERY, CISTERN

Designers shall consider the use of cisterns to capture roof drainage for on-site use. Cistern design should match the expected quantities of recoverable rainfall to planned use, such as toilet flushing, irrigation, or cooling tower make-up. Cistern location should accommodate the configuration of the rainwater collection system, provide convenient access for planned water use, and fit within the aesthetics of the building architecture and building landscape plan.

2.7.4.2 DISTRIBUTED STORMWATER MANAGEMENT TECHNIQUES

To the maximum extent practical, implement distributed stormwater management techniques to minimize the hydrologic effects of development. Distributed management techniques (or integrated management practices) that should be considered include:

- Bioretention facilities
- Dry wells
- Filter/buffer strips and other multifunctional landscape areas
- Grassed swales, bioretention swales, and wet swales
- Infiltration trenches.

2.7.4.3 REDUCE/MINIMIZE TOTAL IMPERVIOUS AREA

Careful consideration should be applied during site lay-out to minimize the total footprint of impervious land use required for roadways, sidewalks, driveways, and parking areas. Where ever practical, porous paving materials shall be used as substitutes for impervious surfaces. Ultimate material selection shall be based on permeability, durability under design traffic load, maintainability and cost effectiveness.

2.7.5 CONVEYANCE

Subsurface and open channel stormwater conveyance systems shall meet the following requirements.

2.7.5.1 STORM SEWERS

Subsurface drainage systems shall be sized to accommodate runoff from the 10-year, 6-hour storm and shall be sized for a greater storm in locations where there is substantial risk to critical facilities and operations. Subsurface system designs shall meet sediment transport requirements. Storm sewers shall be designed to maintain a minimum scour velocity of 2 feet per second. New storm sewers shall be sized for open channel flow. The minimum storm sewer size shall be 15 inches. The minimum culvert size shall be 15 inches. For roof drain systems, the minimum pipe size for laterals and collectors shall be 6 inches.

2.7.5.2 OPEN CHANNELS

Open channel stormwater conveyance systems shall be sized to accommodate the 10-year, 6-hour design flow with a minimum freeboard and shall be sized for a greater storm in locations where there is substantial risk to critical facilities and operations.

Open channel stormwater conveyance systems shall be designed for minimum maintenance. The potential for scour or deposition within earth-lined channels shall be considered before approval by the appropriate EPA authority. Preference for earth-lined or "armored" channels shall be based on a comparison of capital, maintenance, and operation costs. Inlets to open channel stormwater conveyance systems shall be placed at locations where erosion potential is minimal.

2.7.6 STORMWATER QUALITY

Site development shall incorporate quality control measures that reduce the concentration of pollutants in stormwater prior to discharge into receiving waters. Construction sites that disturb one acre or more may be required to obtain a National Pollutant Discharge Elimination System (NPDES) permit, including developing a site pollution prevention plan. See Chapter 3 of Volume 4 of the *EPA Facilities Manual, Environmental Management Guidelines*.

2.7.7 FLOODPLAIN AND WETLANDS DEVELOPMENT

Development, modification, or occupancy of floodplains and wetlands should be avoided, particularly when practical alternatives exist. To the extent possible, EPA shall meet the requirements of Executive Orders 11988 and 11990. EPA shall:

- Avoid, to the extent possible, the long-term and short-term adverse impacts associated with the destruction of wetlands and the occupancy and modification of floodplains and wetlands, and avoid direct and indirect support of floodplain and wetlands development wherever there is a practicable alternative for new development.

- Incorporate floodplain management goals and wetland protection considerations into its planning, regulation, and decision making.

- Carefully consider the potential impacts of any EPA action in a floodplain and the impacts of any new EPA construction in wetlands not located in a floodplain.

- Identify, consider, and, as appropriate, implement alternative actions to avoid or mitigate adverse impacts on floodplains and wetlands.

- Provide opportunity for early public review of any plans or proposals for actions in floodplains or new construction in wetlands.

- Ensure that construction within floodplains or wetlands complies with 10 CFR Part 1022 and NEPA and implementing regulations.

2.7.8 COASTAL DEVELOPMENT

The development of site boating, docking, and seawall facilities shall conform to all federal, state, and local requirements. Development should not allow any dredging and fill dumping at waters edge.

2.8 Utilities and Support Services

2.8.1 WATER DISTRIBUTION SYSTEMS

This subsection applies to water distribution systems for domestic (potable) and industrial (nonpotable) uses. The use of dual water systems (i.e., domestic and industrial or irrigation) is subject to the approval of the appropriate EPA facilities engineering group. Where use of dual water systems is approved, the location and alignment of such systems must be clearly identified by location markers placed throughout the site at intervals specified by the appropriate EPA facilities engineering group. Both systems must also be clearly identified on the record drawings.

- Cross connections between domestic and industrial or irrigation systems are prohibited. Domestic water conveyed within distribution systems that serve EPA facilities shall comply with the applicable Safe Drinking Water Act (SDWA) requirements; 40 CFR Parts 141–142; and all other applicable state, regional, and local requirements. The quality of domestic water within such distribution systems shall be protected from degradation by installation of reduced-pressure principal assembly backflow preventers to prevent backflow of contaminants or pollutants into the system.

- Drinking water in newly constructed facilities must be tested to ascertain compliance with the National Primary Drinking Water Regulations and be tested for lead and copper to insure they do not exceed drinking water action levels. See Chapter 3 of Volume 4 of the *EPA Facilities Manual, Environmental Management Guidelines*.

- Backflow prevention devices shall be installed in accordance with the National Plumbing Code. Only devices approved by the Foundation for Cross-Connection Control and Hydraulic Research shall be used. (Refer to *Manual of Cross-Connection Control* [9th Edition].)

2.8.1.1 PLANNING CONSIDERATIONS

The following considerations shall be incorporated into the project planning.

- During route selection and initial planning for water distribution systems, the following conditions and requirements shall be considered:
  - Projections concerning future population and development
  - Anticipated average daily flow for fully developed conditions
  - Anticipated peak flows for domestic, industrial, fire, and special water usage
  - Hydraulic design criteria
  - Health and safety requirements
  - Physical constraints (e.g., utility corridors and topographic features)
  - Energy conservation and environmental constraints.

- Distribution system layouts shall be as simple and direct as possible. Where feasible, initial planning efforts shall optimize system layouts (e.g., system loop lines) in order to:
  - Facilitate future system expansion
  - Strengthen fire protection capabilities
  - Minimize conflicts with other utilities
  - Reduce maintenance requirements.

- Water distribution systems shall be included within the utility master plan.

2.8.1.2 SYSTEM DESIGN CONSIDERATIONS

Domestic water distribution mains shall be sized to accommodate the greatest anticipated demand (e.g., fire demand, special requirements, or the peak domestic demand). Domestic water distribution systems shall be designed to deliver a peak domestic flow of 2½ times the average daily demand, plus any special demands, at a minimum residual pressure of 20 pounds per square inch (psi) at ground elevation (or higher pressure residual pressure if special conditions warrant).

- Domestic water distribution systems that also serve fire protection requirements shall be designed to satisfy fire flow requirements plus 50 percent of the average domestic requirements plus any industrial or process demands that cannot be reduced during a fire.

- Each fire hydrant within the distribution system must be capable of delivering 1,000 gallons per minute (gpm) at a minimum residual pressure of 20 psi. Where domestic water distribution systems must serve internal fire protection systems (i.e., sprinklers or foamite systems), adequate residual pressures shall be maintained for proper operation of these systems. Fire hydrant branches (from main to hydrant) shall be not less than 6 inches in diameter and shall be no longer than 300 feet. A gate valve shall be installed within each fire hydrant branch to facilitate maintenance. Fire hydrants shall be installed at maximum intervals of 400 feet and shall not be located more than 300 feet from the buildings to be protected. Each building shall be protected by at least two hydrants. All water mains supplying fire protection systems and fire hydrants shall be treated as fire mains and installed in accordance with NFPA 24.

- Water mains shall have a minimum pressure rating of 150 psi. Water distribution systems shall be designed to maintain normal operating pressures of 40 psi to 100 psi (at ground level) in mains and building service lines. Where the gradient across the service area is such that multiple pressure zones are necessary to maintain the normal operating pressures, pressure-reducing valves shall be used to separate each pressure zone. Use of pressure relief and surge relief valves shall be considered, as necessary, to preclude system damage from water hammer.

- Air release and vacuum breaker valves shall be installed, as required, at high points within the distribution system and in long supply mains.

- Distribution system mains shall have a minimum depth of cover of 3 feet. In cold climates, at roadway crossings in high traffic areas, and at railroad crossings, additional cover shall be provided to prevent freezing. Building service lines shall be at least 1 inch in diameter. Service lines that are less than 2 inches in diameter shall be connected to the distribution main by a corporation stop and a copper gooseneck, with a service stop below frost line. Service lines that are more than 2 inches in diameter shall be connected to the distribution main by a rigid connection and shall have a gate valve located below frost line. Risers from frost line to floorlines of buildings shall be adequately insulated. Water storage facilities shall comply with NFPA 22.

- Soil and groundwater conditions (e.g., soil corrosivity) on the site shall be considered in the selection of pipe materials. Where ferrous pipe is installed within the distribution system, insulating couplings shall be installed to prevent galvanic corrosion.

2.8.1.3 WELLHEAD DESIGN CONSIDERATIONS FOR RESEARCH PURPOSES

Where and when water must be provided for fish culture, on-site drilled wells shall be capable of producing a minimum of 20 gallons of water (of consistent quality) per minute unless otherwise required by the EPA project officer. The water must be of a suitable quality for rearing and maintaining fish cultures. It must not be contaminated with pesticides, heavy metals, sulfides, silica, or chlorides. The anions should be those found in natural lakes or streams. Water quality parameters should be as follows:

- Dissolved oxygen: > 6.0 milligrams per liter (mg/L)
- pH: 7.2–8.5
- Hardness: 40–200 mg/L (as $CaCO_3$)
- Alkalinity: Slightly less than hardness
- Iron: < 1.0 mg/L
- Chlorides: < 250 mg/L as chlorides and sulfates
- Sulfides: < 2.0 micrograms per liter (µg/L) as undissociated H_2S.

The well and pump shall be protected from the elements. Two 500-gallon water tanks shall be installed as reservoirs for water prior to distribution.

2.8.2 WASTEWATER COLLECTION SYSTEMS

This subsection applies to sanitary wastewater collection systems (i.e., lift stations, force mains, collector sewers and interceptor sewers, and building sewers 5 feet beyond the building foundation). The following elements shall be considered during wastewater system design:

- Grey water systems should be considered as an environmental design strategy

- Industrial wastewater and pollutants above the minimum concentrations specified by EPA shall be excluded from sanitary wastewater collection systems.

- Pretreatment systems (such as acid neutralization) shall be installed where required and shall meet EPA specifications and/or requirements of the publicly owned treatment works (POTW) and NPDES as applicable.

- Hydraulic design of wastewater collection systems shall comply with TM 5-814-1, Sanitary and Industrial Wastewater Collection; Gravity Sewers and Appurtenances (March 1985), TM 5-814-2, Sanitary and Industrial Wastewater Collection - Pumping Stations and Force Mains (March 1985) and American Society of Civil Engineers (ASCE) 37. All wastewater collection systems shall be designed for gravity flow unless such systems are not economically feasible. Sewage lift stations and force mains shall not be used unless approved by AEAMB. Feasibility analyses and economic evaluations of the costs of lift stations and force mains for construction, operation, and maintenance shall be prepared and submitted to AEAMB for approval. Sewers and force mains shall be sized to accommodate the estimated daily maximum and minimum flow for the initial and final years of the design period. These maximum and minimum flows shall be specified by the appropriate EPA authority in accordance with ASCE 37.

  - Velocities in gravity sewers and force mains shall not exceed 10 feet per second.
  - Gravity sewers shall be designed for a minimum velocity of 2 feet per second.
  - Force mains shall be designed for a minimum velocity of 3½ feet per second.
  - The minimum size pipe for a sanitary sewer between manholes is 8".
  - The minimum size pipe for the sanitary building connection is 6".
  - The minimum slopes for a 6" sanitary sewer is 0.6%.
  - The minimum slope for an 8" sanitary sewer is 0.4%.

- For the preliminary design, domestic water consumption rates shall be used to approximate wastewater flows. For the final design, where possible, actual flow data from an adjacent service area similar to the service area under consideration shall be used to estimate wastewater discharges. In the absence of such data, metered water use, less the consumptive use (i.e., water withdrawal rate), can be used.

- Sewers and force mains shall have a minimum depth of cover of 2 feet. Additional cover shall be provided to prevent freezing in cold climates and at roadway crossings. Sewer and force main trench widths shall be minimized; however, excavations, trenching, and shoring shall comply with 29 CFR Part 1926, Subpart P. Pipe bedding specified by the pipe manufacturer shall be in place before sewers and force mains are installed.

- Sewers or force mains shall not be routed within 100 feet of any well or reservoir that serves as a potable water supply. In all instances where such horizontal separation cannot be maintained, the sewer or force main shall be ductile iron pipe. Where groundwater is near the surface, special precautions shall be taken to prevent sewer infiltration or exfiltration.

- The horizontal distance between the water pipe and a sewer or force main shall not be less than 10 feet except where the bottom of the water line will be at least 12 inches above the top of the sewer pipe or force main, in which case the water pipe shall be laid at least 6 feet (horizontally) from the sewer or force main. Where water pipes cross under gravity-flow sewer lines, the sewer pipe shall be fully encased in concrete for at least 10 feet each side of the crossing or, for this same distance, shall be made of pressure pipe, with no joint located within 3 feet horizontally of the crossing. Water lines shall, in all cases, cross above sewage force mains or inverted siphons and shall be at least 2 feet above the sewer main. Joints in the sewer main that are within 3 feet (horizontally) of the crossing shall be encased in concrete.

- Where feasible, sewers and force mains shall not be routed under buildings or other permanent structures. Sewers and force mains shall be adjacent and parallel to paved roadways. Sewers and force mains shall not pass beneath paved roadways except at roadway crossings. Where feasible, utility cuts within existing roadways shall be perpendicular to the roadway centerline to minimize trench length.

Diagonal roadway cuts shall be avoided whenever possible. Consideration should be given to boring and jacking pipe or directional drilling for roadway crossings.

- The selection of sewer and force main material shall be based on wastewater characteristics and soil conditions. Inverted siphons using high density polyethylene (HDPE) pipe shall be used for sanitary sewer stream crossings. HDPE pipe placed below the stream bed shall be used for force main stream crossings. Ductile iron shall also be used for sewers placed at shallow depths (3' or less) under paved surfaces subject to vehicular traffic. Infiltration-exfiltration test requirements shall be specified within the contract documents.

2.8.3 NATURAL GAS DISTRIBUTION SYSTEMS

Gas distribution shall comply with local codes and requirements. Fuel gas systems shall comply with NFPA 54. Liquefied petroleum gas systems shall comply with NFPA 58.

2.8.4 ELECTRICAL DISTRIBUTION SYSTEMS

Site power and lighting shall be coordinated as detailed in Section 16, Electrical Requirements, of this Manual.

2.8.5 TELECOMMUNICATIONS SYSTEMS

Site communications shall be coordinated as detailed in Section 16.14 of this Manual.

2.8.6 SOLID WASTE COLLECTION SYSTEMS

Management of hazardous waste shall comply with Subtitle C of RCRA (see *EPA Facilities Manual*, Volume 4). Management of nonhazardous solid waste shall comply with Subtitle D of RCRA. In addition, each building should accommodate a nonhazardous waste recycling program, with areas for collection/separation convenient to each work area as well as a central recycling space for building-wide collection, separation, and storage. The recycling program should be planned for recycling paper, glass, plastics, metals, and toner cartridges. Recycling bins conforming to EPA's standards shall be planned for and provided for relevant support spaces as indicate in Section 1 of this Manual.

Building corridors, elevators, trash rooms, and/or loading docks shall accommodate collection hampers and containers for aggregating, moving, and temporarily storing recyclable materials. The loading dock shall accommodate the installation and operation of a compactor for mixed office paper and/or corrugated cardboard.

END OF SECTION 2

Section 3 - Concrete

3.1 General Requirements

3.1.1 DESIGN AND CONSTRUCTION

This section covers the design and construction of plain, reinforced, and prestressed concrete structures, whether of cast-in-place or precast concrete construction. The use of recycled materials in cast-in-place and precast applications is encouraged, to the extent permitted by state codes. The requirements of this section shall be used in conjunction with the structural design sections.

3.1.2 CODES

Concrete materials, design, and construction for buildings and other structures shall comply with American Concrete Institute (ACI) 318 and local building codes, as applicable.

3.1.3 USE OF RECOVERED MATERIALS IN CONCRETE

Use of coal fly ash, or any additives, in concrete shall be governed by state building codes. Additives in floor slabs should be minimized to avoid interaction with adhesives or sealants. [Note: Testing for toxic contaminants should not be necessary if using materials covered under the CPG.]

3.2 Concrete Formwork

Formwork for concrete construction shall comply with ACI 347R, ACI SP-4, and state building codes, as applicable.

3.3 Concrete Reinforcement

3.3.1 REINFORCEMENT MATERIALS

Reinforcement materials for buildings and other incidental structures shall comply with state building codes and ACI 318, as applicable.

3.3.2 REINFORCEMENT DETAILS

Reinforcement details shall comply with ACI SP-66, ACI 318, and state building codes, as applicable.

3.4 Cast-In-Place Concrete

3.4.1 GENERAL

This subsection covers the selection of materials; proportioning of mixes; and mixing, placing, testing, and quality control of cast-in-place concrete.

3.4.2 MATERIALS, TESTING, AND QUALITY CONTROL

Materials, testing, and quality control shall comply with ACI 318 and state building codes. Recycled non-hazardous materials and recovered materials as designed in the CPG shall be used in concrete mixes to the extent permitted by state building code.

3.4.3 TOLERANCES

Tolerances shall be as recommended in ACI 347R, ACI 117, and state building code.

3.4.4 SELECTING PROPORTIONS FOR CONCRETE MIXES

The proportions for concrete mixes of normal-weight concrete shall comply with state building code and ACI 211.1. The proportions for structural lightweight concrete shall comply with state building code and ACI 211.2.

3.4.5 MIXING, TRANSPORTING, AND PLACING

Mixing, transporting, and placing shall comply with the recommendations of state building code and ACI 304R.

3.4.6 CLIMATIC CONSIDERATIONS

Hot-weather concreting shall comply with the recommendations of state building code and ACI 305R. Cold-weather concreting shall comply with the recommendations of state building code and ACI 306R.

3.4.7 POST-TENSIONED CONCRETE

In addition to the standards and resources referenced in other subsections, the Post-Tensioning Institute (PTI) *Post-Tensioning Manual* may be used for the design and construction of post-tensioned concrete structures.

3.5 Precast/Prestressed Concrete

3.5.1 STRUCTURAL

This subsection covers materials, design, and construction of precast, precast and prestressed, and precast and post-tensioned structures. In addition to meeting the requirements of other subsections, precast concrete shall comply with the Precast/Prestressed Concrete Institute Manual (PCI MNL)-116. PCI MNL-120 and the PTI *Post-Tensioning Manual* may also be used as guides for the design and construction of precast concrete structures.

3.5.2 ARCHITECTURAL

This subsection covers materials, design, and construction of architectural precast, and architectural precast and prestressed, concrete members. In addition to meeting the requirements of other subsections, architectural precast members shall comply with the PCI MNL-117 and PCI MNL-122.

3.6 Cementitious Decks for Buildings

3.6.1 GENERAL

This subsection covers materials, design, and construction of cementitious decks for building structures and prefabricated floor and roof systems such as:

- Lightweight precast reinforced concrete planks
- Lightweight precast reinforced concrete channel slabs
- Reinforced gypsum planks
- Structural cement-fiber roof deck systems
- Reinforced poured-gypsum-over-formboard roof systems.

3.6.2 MATERIALS, DESIGN, AND CONSTRUCTION

The materials, design, and construction of cementitious decks for buildings shall comply with the requirements of local building codes, manufacturer's recommendations, and CPG guidelines for recovered material content. In the event of a conflict between the local building code and the manufacturer's recommendations, the more stringent shall apply.

3.7 Repair and Restoration of Concrete Structures

This subsection covers the evaluation of damage or deterioration, selection of repair methods, surface preparation, and repair and restoration of concrete structures. The materials covered are Portland cement mortars and concretes, latex-modified Portland cement mortar, epoxy mortars, epoxy concrete, and methyl methacrylate concrete. Methods, procedures, and materials for the repair and restoration of concrete structures shall comply with the state building code and guidelines ACI 503.4 and ACI 546.1R.

3.8 Concrete Inspection and Testing

Inspection and testing shall comply with the requirements of the state building code and ACI 318.

END OF SECTION 3

Section 4 - Masonry

4.1 General Requirements

4.1.1 DESIGN AND CONSTRUCTION

This section covers the design and construction of masonry structures. It shall apply to unit masonry construction; reinforced and un-reinforced masonry structures; structures using cement, clay, and stone products; and those including brick, block, and tile structures. The requirements of this subsection shall be used in conjunction with those in other sections and subsections.

4.1.2 CODES AND SPECIFICATIONS

Materials, design, and construction of masonry structures shall comply with the requirements of the state building code. Recycled non-hazardous materials shall be used to the extent practical and allowed by state building code. Local sources shall be used to the extent practical. The following sources shall also be used as guides for the design of masonry structures: The publications are referred to in the text by basic designation only.

- American Concrete Institute (ACI) 53 Building Code Requirements for Masonry Structures
- ACI 530.1 Specifications for Masonry Structures

4.2 Mortar and Grout

4.2.1 GENERAL

Requirements for materials, mixing, strength, and specifications for mortar and grout used in masonry structures shall comply with state building codes.

4.2.2 MORTAR

Mortar shall be designed to comply with:

- ASTM C 270 Mortar for Unit Masonry

Mortar shall be designed per requirements of state code to perform the following functions:

- Join masonry units into an integral structure.
- Create tight seals between masonry units to prevent the entry of air and moisture.
- Bond with steel joint reinforcement, metal ties and anchor bolts, where used, so that they act integrally with the masonry.
- Give exposed masonry surfaces a desired architectural quality through color contrasts or shadow line from various joint-tooling procedures.
- Compensate for size variations in the units by providing a bed to accommodate the different unit sizes.
- Portland cement mortar should be used for all structural brickwork.

4.2.3 GROUT

Grout shall be used in reinforced load-bearing masonry construction to bond the masonry units and the reinforcing steel so that they act together to resist the imposed loads. It may also be used in un-reinforced load-bearing masonry construction to give it added strength. Grout shall comply with:

- State building code, as applicable
- ASTM C 476 Grout for Masonry

4.3 Unit Masonry

Materials, design, and construction of masonry units shall be in accordance with the requirements in subsection 4.1, General Requirements and the following:

- Solid Clay or Shale Brick - ASTM C 62, Building Brick (Solid Masonry Units Made from Clay or Shale)
- Hollow Clay or Shale Brick - ASTM C 652, Hollow Brick (Hollow Masonry Units Made From Clay or Shale)
- Concrete Brick - ASTM C 55, Concrete Brick
- Hollow and solid concrete masonry units - ASTM C 90, Loadbearing Concrete Masonry Units
- Prefaced concrete masonry units - ASTM C 744, Prefaced Concrete and Calcium Silicate Masonry Units, using masonry units conforming to ASTM C 90
- Ceramic glazed structural clay facing units - ASTM C 126, Ceramic Glazed Structural Clay Facing Tile, Facing Brinc, and Solid Masonry Units

4.4 Masonry Accessories

Joint reinforcement, anchors, and ties shall be zinc-coated and shall comply with the following:

- State building code and as applicable
- ACI 530.1.

4.5 Masonry Inspection and Testing

Inspection and testing of unit masonry, grout, mortar reinforcing, and accessories shall comply with the following:

- State building code and as applicable
- ACI 530.1

4.5.1 SPECIAL INSPECTION

When the masonry compressive strength (f'm) used in design is more than 1500 psi, a qualified independent masonry inspector approved by the Contracting Officer's Representative shall perform inspection of the masonry work. Minimum qualifications for the masonry inspector shall be 5 years of reinforced masonry inspection experience or acceptance by a State, municipality, or other governmental body having a program of examining and certifying inspectors for reinforced masonry construction. The masonry inspector shall be present during preparation of masonry prisms, sampling and placing of masonry units, placement of reinforcement (including placement of dowels in footings and foundation walls), inspection of grout space, immediately prior to closing of cleanouts, and during grouting operations. The masonry inspector shall assure Contractor compliance with the drawings and specifications. The masonry inspector shall keep a complete record of all inspections and shall submit daily written reports to the Quality Control Supervisory Representative reporting the quality of masonry construction.

END OF SECTION 4

Section 5 - Metals

5.1 General Requirements

This section covers the design and construction of steel and aluminum structures. The requirements of this section shall be used in conjunction with those of other sections. Reused and/or recycled materials shall be used to the extent practical and permitted by code.

5.2 Structural Steel

Structural steel for buildings and other incidental structures shall comply with the following:

- State building code as applicable
- American Institute of Steel Construction, Inc., (AISC) ASD Manual of Steel Construction.
- AISC LRFD Manual of Steel Construction

5.3 Steel Joists

5.3.1 CODES AND SPECIFICATIONS

Steel joists and joist girders shall comply with the following:

- State building code as applicable
- Steel Joist Institute (SJI) Standard Specifications: Load Tables and Weight Tables for Steel Joists and Joist Girders.

5.4.2 INTENDED USE

Steel joists shall not be used for wind bracing or other types of bracing. They shall be used only as horizontal load-carrying members supporting floor and roof decks.

5.4.3 SUPPORT OF VIBRATING EQUIPMENT

Steel joists shall not be used to support air-conditioning, air-handling, or any type of vibrating equipment. Steel joists serving as floor joists and roof purlins shall not have bracing members attached to them that would transmit vibrations from vibrating equipment into the steel joists and/or structural diaphragms.

5.4 Steel Decks

Steel decks shall comply with the following:

- State building code as applicable
- Steel Deck Institute (SDI) Diaphragm Design Manual
- SDI Design Manual for Composite Decks, Form Decks, and Roof Decks

5.5 Miscellaneous Metals

5.5.1 DEFINITION

Miscellaneous metals are all ferrous and nonferrous metals other than structural steel as defined in the AISC Code of Standard Practice.

5.5.2 CODES AND SPECIFICATIONS

Miscellaneous metals shall comply with the requirements of local orders and with all applicable industry standards for the specific type of metal and use, as listed elsewhere in this section.

5.6 Cold-Formed Steel

Cold-formed steel shall comply with the following:

- State building code as applicable
- American Iron and Steel Institute (AISI) Specification for the Design of Cold-Formed Steel Structural Members.
- AISI Cold-Formed Steel Structural Members

5.7 Pre-engineered Metal Buildings

5.7.1 CODES AND SPECIFICATIONS

Pre-engineered metal buildings shall comply with:

- State building code as applicable
- The Metal Building Manufacturers Association's *Metal Building Systems Manual*.

5.7.2 LOADS

Design loads shall conform to requirements of state building code.

5.8 Structural Steel Inspection and Testing

Structural steel inspection shall be required and performed in conformance with requirements of:

- State building code as applicable
- AISC Manual of Steel Construction.

END OF SECTION 5

Section 6 - Wood and Plastics

6.1 General Requirements

This section covers the use of wood and plastic materials in construction. The use of recycled materials should be maximized, as applicable, in accordance with the requirements of RCRA and designated products published in EPA's Comprehensive Procurement Guidelines (CPG). The use of recovered materials should conform to requirements of industry practices, standards, and state codes, as applicable. Other environmental design considerations include:

- Composite woods, plywood, particleboard containing no urea-formaldehyde
- Wood products certified by the Forest Stewardship Council to be from managed sources

6.2 Partitions

Standardization of interior partitions is desirable. Partitions within administrative areas should be easily removable. Sound isolation and laboratory partitions between modules shall be designed to be removable in order to accommodate future reconfiguration of spaces. Partitions requiring fire-resistance ratings shall be constructed of noncombustible/limited combustible (NC/LC) materials and either listed by Underwriters Laboratories Inc. (UL) or approved by Factory Mutual and listed in its approval guide. Refer to the description of off-gassing in Chapter 5 of the *Safety Manual* for more information on indoor material requirements. See also www.cpg/gov for shower and restroom dividers/partition containing recovered materials.

6.2.1 SUBDIVIDING PARTITIONS

Office subdividing partitions shall comply with the applicable local building code and/or National Fire Protection Association (NFPA) 101 requirements. These partitions must be provided at a ratio of 1 linear foot per 10 square feet of space, as applicable. Partitioning over interior office doors is included in the measurement. Partitions must extend from the finished floor to the finished ceiling and have a flame spread rating of 25 or less, a smoke development rating of 450 or less (American Society for Testing and Materials [ASTM] E-84 Test), and a minimum sound transmission loss (STL) rating of 40.

6.2.2 PERMANENT PARTITIONS

Permanent partitions must be provided, as necessary, to surround stairs, corridors, elevator shafts, toilets, janitor closets, meeting and conference rooms, and mechanical rooms. They shall have a flame spread and smoke developed criteria per NFPA 101, Table A.10.2.2 and/or a flame spread rating of 25 or less and a smoke development rating of 450 or less (ASTM E-84 Test), whichever is more stringent. Stairs, elevators, and other floor openings shall be enclosed by partition(s) and have the fire resistance required by applicable codes. These partitions shall extend from the floor to the underside of the structure above, shall effectively isolate sound and vibration, and shall meet all fire separation requirements.

6.2.3 WOOD STUD PARTITIONS

Wood studs shall not be installed as part of new construction or as part of a major alteration or space adjustment in other types of construction.

6.2.4 LESS-THAN-CEILING-HIGH PARTITIONS

Bank type partitions, acoustical screens, freestanding space dividers, and other partitions that do not reach the ceiling shall conform to the requirements for movable partitions set forth by the General Services Administration (GSA) in PBS-P100. In addition, the placement of partitions relative to sprinklers shall comply with NFPA 13, and adequate passageway width and identification of means of egress shall comply with NFPA 101. Another factor limiting the height and location of partitions is that tall or massive partition systems may interfere with the even distribution of conditioned air and natural light. Consideration should be given to the location of supply diffusers and return registers; the location of thermostats; and the clearance above, below, and around the partitions to allow adequate air circulation.

6.3 Use of Wood and Plastic

Selection of wood, adhesives, and plastic materials should conform to requirements of flame spread and smoke developed criteria per NFPA 101, Table A.10.2.2, 2000 edition; and should be of a low VOC-emitting or low ozone-depleting material. Treated lumber should not be used for furnishings, especially for play equipment in day-care centers. Laboratory shelving and casework may be fabricated using wood (plywood) and plastic materials. See subsection 10.5 of this Manual for requirements.

END OF SECTION 6

Section 7 - Thermal and Moisture Requirements

7.1 General Requirements

In selecting building materials, careful consideration shall be given to all technical criteria. Vapor and infiltration barriers to vapor flow through the walls and roofs shall be placed with the aim of preventing moisture accumulation and condensation within the building structure, reduction of thermal performance, and increased latent cooling load in the space. The use of recovered materials should be maximized, as applicable, in accordance with the requirements of RCRA and designated recycled content thermal insulation products published in EPA's Comprehensive Procurement Guidelines (CPG). The use of recycled materials should conform to requirements of industry practices, standards, and state codes, as applicable. Additionally, selection of materials should conform to requirements of flame spread and smoke developed criteria per NFPA 101, Table A.10.2.2, 2000 edition; and should be of a low VOC-emitting or low ozone-depleting type material.

7.2 Design Characteristics

Design characteristics of exterior wall sections should be evaluated for functional and cost effectiveness in relation to the following:

- Moisture transport
- Thermal performance
- Weathertight design, including sealant profiles, material adjacencies, and flashing configuration
- Air flow and infiltration.

7.3 Thermal Resistance

For information on the thermal characteristics of single materials or wall assemblies, refer to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) *Handbook of Fundamentals* or the manufacturer's certified technical information. Thermal resistance (R) values shall be identified for each element in the building shell. "U" factor calculations are prepared by following the recommended procedures as documented in the ASHRAE *Handbook of Fundamentals.*

7.4 Moisture Transport

Dew point calculations are prepared by following the recommended design procedures in the ASHRAE *Handbook of Fundamentals*. The exterior envelope will be designed to prevent condensation within wall cavities, building spaces, etc.

7.5 Panel, Curtain, and Spandrel Walls

Openings between panel, curtain, and spandrel walls and the building structure or floor slabs around them, shall be fire stopped in accordance with the provisions outlined in Section 13, Special Construction, of this Manual. The requirements in this subsection in no way reduce the requirements for protection of walls subject to an exterior fire exposure. See Chapter 2 of the *Safety Manual* for information on exposure protection.

7.5.1 PANEL AND CURTAIN WALLS

All panel and curtain walls shall conform to the requirements for nonbearing walls for the type of construction and model code involved and shall be securely anchored to the building in a manner that will prevent failure of the anchors in a fire or failure of the panel and its components in high wind.

7.5.2 SPANDREL WALLS

Except as noted below, spandrel walls shall be provided at each floor and shall have a height of at least 3 feet above the finished floor and a fire resistance equivalent to the floor involved.

7.5.2.1 EXCEPTION NO. 1

Exterior spandrel walls are not necessary and, if provided, are not required to have any fire resistance if the rooms located directly inside the exterior wall of the building and on the floor below contain low-hazard occupancies or occupancies that are sprinkler protected.

7.5.2.2 EXCEPTION NO. 2.

Spandrel walls are not required at grade level.

END OF SECTION 7

Section 8 - Doors and Windows

8.1 Doors

8.1.1 GENERAL

Unless otherwise noted, all doors shall be 36 inches wide. Doors in designed egress ways shall swing in the direction of egress. Doors shall not swing into exit ways in a manner that reduces the effective exit width. Doors and windows shall conform to requirements of National Fire Protection Association (NFPA) 80, as applicable.

8.1.1.1 HARDWARE

All doors shall be equipped with heavy-duty hardware. Each leaf (up to 80 inches high) shall be provided with minimum 1½ pair butts (hinges) or 2 pair butts (hinges) on doors higher than 80 inches. All doors shall be provided with appropriate stops or wall bumpers. Exterior, egress, and laboratory doors shall be provided with appropriate closers. All public-use doors must be equipped with push plates, pull bars or handles, and automatic door closers. Corridor and outside doors must be equipped with cylinder locks and door checks. All locks must be master-keyed. The Government must be furnished with at least two master keys and two keys for each lock. Hardware for doors in the means of egress shall conform to NFPA standard 101 and American with Disabilities Act (ADA)

8.1.1.2 ENVIRONMENTAL CONSIDERATIONS

Doors, windows, and hardware exposed to highly corrosive conditions, as in marine or very humid environments, shall be nonferrous or provided with a protective, corrosion-resistant finish. Selection and location of door systems must include consideration of their designed protection against infiltration and the outdoor air pollutants that might pass through the openings.

8.1.2 EXTERIOR DOORS

Exterior doors shall be weathertight and equipped with door closer, shall open outward, and shall have a drip rain diverter above the door as required. Doors shall comply with requirements of the Uniform Federal Accessibility Standards (UFAS), Americans with Disabilities Act (ADA), and NFPA 101, as applicable. Exterior doors shall be alarmed for anti-intrusion.

8.1.3 INTERIOR DOORS

Interior doors must have a minimum opening of 36 inches (width) by 80 inches (height) and shall comply with ADA and/or UFAS, as applicable. Hollow-core wood doors are not acceptable. Hardware shall be ADA compliant. Doors shall be operable by a single effort and shall be provided with vision panels in accordance with all applicable code requirements. All requirements of ADA shall be incorporated.

8.1.3.1 LANDING AREAS

The landing areas for doors that open onto walkways, ramps, corridors, and other pedestrian paths shall be clear and level with a slope of no greater than 1:50; they shall extend at least 5 feet from the swing side of the door, 4 feet from the opposite side, and at least 1½ feet past the latch side (pull side) of the door and 1 foot past the latch side (push side).

8.1.4 FIRE DOORS

Fire doors shall conform to NFPA 80. Doors, hardware, and frames shall bear the label of Underwriters Laboratories, Factory Mutual, or another approved laboratory testing organization, in accordance with American Society for Testing and Materials (ASTM) E-152.

Glazing material shall not be allowed in fire doors with a 3-hour fire protection rating or in fire doors with a 1.5-hour fire protection rating that are used in locations with severe fire exposure potential (such as in a flammable-liquids storage room). The maximum area of glazing in a 1- or 1.5-hour door shall be 100 square inches (0.065 square meters) unless the area has been tested and meets the requirements of NFPA 80. The area of glazing in fire doors that have less than 1-hour fire-resistance ratings shall be limited to the maximum area tested. All glazing shall be wired glass or other glass approved for use in fire doors.

8.1.4.1 EXIT DOORS

Fire doors in exits or means of egress shall also conform to the requirements contained in Chapter 2 of the *Safety Manual*. Fire doors in air-handling systems shall also conform to the requirements outlined in Section 15, Mechanical Requirements, of this Manual.

8.1.5 LABORATORY DOORS

Laboratory doors shall be 48 inches wide (36 inches wide for the active leaf and 12 inches wide for the inactive leaf) and 84 inches high to facilitate easy movement of equipment and carts. Laboratory doors shall swing in the direction of egress from the laboratory and should be inserted in alcoves regardless of the corridor width. Open doors should not protrude more than 6 inches into exit corridors. In general, large vision panels should be provided to allow easy and quick safety inspection of laboratory spaces. Hardware shall be ADA-compliant and shall provide various levels of access control as required; it will include both combination and key access locks. Areas where a high level of security will be required shall be provided with card-key access control.

8.2 Windows

8.2.1 GENERAL

The use of natural but controlled daylighting should be maximized as part of a total energy conservation program. EPA values natural light and perceives it as part of an exemplary working environment as well as a potential source of energy savings. The building organization and design concept shall bring adequate natural light into personnel spaces. Window size, head-height, placement, umber, and location shall be determined on the basis of need for natural light and ventilation and of energy considerations. All exterior windows in heated or air-conditioned spaces shall use double-glazed, insulated, low E glass and thermal break sashes. All windows in laboratory rooms that may contain explosive materials shall be glazed with safety glass. Selection and location of windows must include consideration of their designed protection against infiltration and the outdoor air pollutants that might pass through the openings.

8.2.2 FIXED WINDOW SYSTEMS

Laboratory space shall have windows that are non-operable (except with a key, where windows must be opened for cleaning purposes) in order to maintain temperature and humidity control and room pressurization relationships.

8.2.3 SAFETY OF STOREFRONT AND CURTAIN WALL SYSTEMS

Windows extending to within 18 inches of the floor and located at least 4 feet above grade shall be provided with a safety bar on the interior window approximately 3 feet above floor level. Off-street, ground-level windows and those accessible from fire escapes and adjacent roofs must have anti-intrusion alarm systems to deter forcible entry.

8.2.4 WINDOW HEIGHT

Wherever windows extend to within 36 inches of the finished floor and are at least 4 feet above grade, a suitable metal barrier shall be provided on the interior side, approximately 56 inches above floor level. (Perimeter heating and cooling units may form this barrier.) If the glass construction can withstand a horizontal force of 200 pounds or more and meets the requirements of 29 CFR §1910.23, 16 CFR Part

1201, and the local building code, no barriers are required. For windows in walls that must have a fire-resistance rating, see NFPA 80A and Chapter 2 of the *Safety Manual*.

8.2.5 GLAZED PANELS IN INTERIOR PARTITIONS AND WALLS

Interior glazed panels must comply with the Consumer Products Safety Commission Safety Standard for Architectural Glazing Materials (16 CFR Part 1201). When glazing panels and windows are used in fire barrier walls, such use shall also meet the criteria set forth in the *Safety Manual*.

8.3 Permanent Window Coverings

8.3.1 GENERAL

The design professional shall be responsible for providing permanent window coverings for interior and exterior windows where required. Nonpermanent window coverings installed on the inside of windows are considered “interior finishes” and are discussed in subsection 9.6 of this Manual.

8.3.2 SUN SHADING

The use of reflective glass shall be reviewed and considered for all exterior windows. The two basic types of reflective glass available for consideration are solar-reflective and low-emissivity (Low-E). The major differences are visible light transmission, wavelengths of energy that are reflected, and the direction in which these wavelengths are usually reflected. Solar-reflective glass has a mirror-like coating that is highly reflective of solar energy. Low-emissivity (Low-E) glass has a metal or metallic-oxide coating that is nearly invisible to the eye. Low-E glass reduces energy costs by creating a heat barrier that helps keep heat outside in the summer and inside in the winter. Low-E glass is suitable for all climates and is available for use in double and triple insulating glass units. Insulating units with an outer panel of tinted or reflective glass can provide added energy cost efficiencies. Use a target of 70% visible light transmission (VLT). Manufacturer’s data sheets should be referred to in order to evaluate shading coefficient and relative heat gain. Use of reflective glass shall be considered even when not required by the data sheet, when solar glare and heat gain should be controlled. Laboratory windows exposed to direct sunlight shall be shaded with permanent exterior shading devices that shade the window from direct sun.

8.3.3 SECURITY

Windows at ground level shall be covered with Mylar to provide security.

END OF SECTION 8

Section 9 - Finishes

9.1 Interior Finishes

The required finishes for each room are specified in the room data sheets included in Appendix C or finish schedules in PORs. The following requirements apply to interior finishing.

9.1.1 TRIM AND INCIDENTAL FINISHES

Interior wall and ceiling finish that covers no more than 10 percent of the aggregate wall and ceiling area involved may be Class C material in accordance with National Fire Protection Association (NFPA) 101, Chapter 6.

9.1.2 FINAL FINISHING MATERIAL

Wallpaper, paint, veneer, and other thin finishing materials that are applied directly to the surface of walls and ceilings and are not more than 1/28-inch thick shall not be considered as interior finishes per NFPA 101, Chapter 6. To the extent practicable, consolidated and/or reprocessed latex paint consistent with CPG guidance should be used.

9.1.3 AIRSPACE

Whenever an airspace is located behind combustible material, the space shall be blocked so that no void extends more than 10 feet in any direction. For example, wood paneling applied to wood furring strips will meet the requirement if the distance between the furring strips is no more than 10 feet in both a horizontal and a vertical direction.

9.1.4 COMBUSTIBLE SUBSTANCES

Materials composed of basically combustible substances (e.g., wood, fiberboard) that have been treated with fire-retardant chemicals throughout the material (e.g., pressure impregnation), as opposed to surface treatment, may be used as interior finish subject to the following conditions: (1) the treated material shall be installed in full accordance with the manufacturer's instructions and (2) the treated material shall not be installed in any location where conditions exist that may reduce the effectiveness of the fire-retardant treatment (e.g., high humidity). Surface treatments may be used to reduce the risks associated with existing conditions, in accordance with Chapter 6 of NFPA 101. No material that will result in higher flame spread or smoke development ratings than those permitted in this Manual shall be used as an interior finish. Finishing materials should conform to flame spread and smoke developed criteria requirements per NFPA 101, Table A.10.2.2, 2000 edition.

9.1.5 ENVIRONMENTAL CRITERIA

The selection of interior finishes shall consider indoor air quality (e.g., low VOC paints, adhesives, caulks, non-chlorine based wall base, wall covering, and flooring) and maximum recycled content for carpet, wallboard, wall base, concrete, steel, and ceiling tiles consistent with CPG requirements and recommendations. Evaluation of materials also should consider the manufacturer's required preparation and cleaning products and the potential for use of low-toxicity cleaning products.

9.2 Wall Treatments

9.2.1 WALL MATERIALS

Wall materials must be capable of withstanding washing with detergents and disinfectants. Materials selected shall be compatible with their intended use and shall emphasize durability and low maintenance while creating a comfortable work environment. Recycled content laminated paperboard and/or structural fiberboard should be specified consistent with CPG guidance.

In general, walls shall be gypsum wallboard, with a painted finish, on metal studs. Walls in laboratory areas will be required to support additional loads due to movable casework, mounting rails, upper cabinets or adjustable shelves, and equipment anchorage. Therefore, structural wall studs, backing plates, and lateral bracing sufficient to withstand heavy loads will be required. Where concrete masonry unit (CMU) block or poured concrete walls are used to meet other design requirements or constraints, they shall be furred with gypsum wallboard or covered with another appropriate finish.

9.2.3 WALL FINISHES

Wall finishes, and the process by which they are selected, must meet the requirements outlined in the following subsections.

9.2.3.1 GENERAL

The required finishes must be designated for each room in the room data sheets. Actual material selection, color, and texture, is left to the design professionals who shall make selections in consultation with the users. Material safety data sheets (MSDS) are a good resource for environment evaluation. Paint shall be carefully selected so as not to affect laboratory operations. The design professional must also select finish materials for items and areas not specifically designated in the room data sheets. These selections shall be submitted to the Government representative for final approval.

9.2.3.2 FLAME SPREAD AND SMOKE LIMITATIONS

Wall finishes on walls that are part of a means of egress must have an interior finish of Class A (flame spread 0-25, smoke developed 0-450). (Interior finish ratings are derived from American Society for Testing and Materials [ASTM] E-84 and NFPA 255.) For any existing construction that is not protected throughout by a sprinkler system meeting the Government's approval, wall finishes must have an interior finish of Class A (flame spread 0-25, smoke developed 0-450). All new construction for EPA shall be protected throughout by a sprinkler system meeting the Government's approval; in construction that is so protected, wall finishes in all areas, except those that are a part of the means of egress, may have an interior finish of Class B (flame spread 26-75, smoke developed 0-450), unless otherwise restricted by an applicable code. The most restrictive requirement shall govern. In sprinkler-protected exit accesses or passageways, the interior finish may be composed of materials with a Class B interior finish rating (flame spread 26-75, smoke developed 0-450). (See NFPA 101 and PBS-P100 as the sources of this requirement.)

9.2.3.3 WALL COVERINGS

Wall covering made of materials that are considered "environmentally friendly" shall be provided in the administrative and other office areas when required (none shall be provided in the laboratory areas). Such wall covering shall meet the following criteria:

- Construction: All material shall be of uniform color throughout. Colors and patterns shall be chosen and approved by EPA from standard manufacturer lines offered by the design professional. Non-chlorine based materials are preferrable.

- Maintenance properties: All wall covering shall be resistant to permanent stains and mildew and shall be capable of being cleaned with mild, nonabrasive cleaners.

- Fire hazard requirements: Each type of wall covering used will have a minimum interior finish of Class C (flame spread 76-200, smoke developed 0-450) when tested in accordance with ASTM E-84.

- Application: Application of all wall covering shall be in accordance with the manufacturer's recommendations. In the product selection process, consider the VOC impact of the manufacturer's recommended application.

9.3 Finished Ceilings

9.3.1 GENERAL

Ceilings shall be set at a minimum height of 9 feet 8 inches in laboratory zones both in general spaces and in laboratory spaces and at a minimum height of 8 feet in corridor and office spaces. Except in service areas, ceilings must have acoustical treatment acceptable to the contracting officer, a flame spread rating of 25 or less, and a smoke development rating of 450 or less (ASTM E-84). Protrusion of fixtures into traffic ways is not allowed. Refer to the *Safety Manual* for fire-resistance requirements for ceilings.

9.3.2 CEILINGS NOT ALONG EXIT PATH

Ceilings and interior finishes in areas that are not part of the normal exit route may have an interior finish of Class C (flame spread 76-200, smoke developed 0-450), unless an applicable code is more restrictive.

9.3.3 CEILINGS ALONG EXIT PATH

In sprinkler-protected exit ways or enclosed corridors leading to exits, ceilings and interior finishes may be composed of materials with an interior finish rating of Class B (flame spread 26-75, smoke developed 0-450), unless an applicable code is more restrictive. The most restrictive applicable code shall be used.

9.3.4 CEILING FINISHES

Where ceiling finishes are required, they will, in general, be suspended acoustical tile. Other ceiling finishes will be required in special rooms, as specified on the room data sheets. These finishes will include hard ceilings with sealed openings for clean analytical laboratories. Special consideration shall be given to the type of grid system and acoustical tile when the ceiling is in a moist area or in food service and other specialty areas. Ceilings in extraction, preparation, glassware washing, microbiology, and similar wet laboratories shall be of water-resistant tile materials or painted gypsum wallboard.

9.3.5 OPEN CEILINGS

All areas above open ceilings shall be sealed and painted. The necessary coordination shall occur for all requirements regarding painting of exposed areas, including engineered systems that require color-coded painting or stenciling and general code-required stenciling of nomenclature defining the rating of fire walls.

9.4 Floor Treatments

9.4.1 GENERAL

Floor finishes shall be compatible with the intended use of the room and shall emphasize durability and low maintenance. Floors and floor coverings may be of any material normal to the intended use. Materials may be either combustible or noncombustible, including wood, asphalt tile, carpet, rugs, linoleum, concrete, and terrazzo. When floor tiles or carpet are used, preference should be given to such items designated in the CPG. Interior floor finishes shall meet the interior finish requirements noted above. (See subsection 9.1.1 for more information on interior finish requirements.) Materials must be smooth, nonabsorbent, skid-proof, and wear resistant. Laboratory flooring should resist the adverse effects of acids, solvents, and detergents. When a seamless floor material is required, the base shall also be seamless and integrally coved. Materials must be monolithic or have a minimum number of joints. The base may be a 4-inch rubber base or an integral-coved base where sheet flooring is used.

9.4.1.1 FIRE SAFETY

Interior floor finishes shall be in accordance with Chapter 6 of NFPA 101 and shall be tested in accordance with NFPA 253. Flooring materials used as wall sections or wall coverings shall comply with the fire safety characteristics described in Chapter 2 of the *Safety Manual* for flame spread and smoke development. The flame spread and smoke development characteristics shall be determined through testing in the orientation in which the material is to be installed (NFPA 253 results shall not be used to evaluate flooring tested in the vertical position).

9.4.2 CARPET

Carpet tiles shall cover all typical office floors and must meet the static buildup and flammability requirements that follow.

9.4.2.1 SPECIFICATIONS

The following specifications must be met for all new carpet installation:

- Pile yarn content: Continuous, solution-dyed filament soil-hiding nylon or wool/nylon combinations.
- Carpet pile construction: Level loop, textured loop, level cut pile, or level cut/uncut pile.
- Pile weight: Minimum of 28 ounces per square yard.
- Secondary back: Recycled content, synthetic fiber, or jute for glue-down installation. Backings with latex and 4PC should be avoided.
- Total weight: Minimum of 64 ounces per square yard.
- Flammability: In all areas except exits, carpet must have a critical radiant flux (CRF) of 0.25 or greater, with a specific optical density not higher than 450. Carpet in exits must have a CRF of at least 0.50. Carpet passing the Consumer Products Safety Commission FFL-70 (Pill Test) is acceptable for office areas; it may also be used in corridors that are protected by automatic sprinklers. Check applicable codes for any more restrictive requirements. The most restrictive requirement shall apply.
- Static buildup: 3.5 kilovolts (kV) maximum with built-in static dissipation is recommended; static-controlled is acceptable. More restrictive levels shall be required in sensitive areas such as computer rooms; these levels shall be determined by calculations for any special equipment in use.
- Interior finish requirements: As required by NFPA 101, Section 6-5.
- End of life/disposal: Required to be recyclable by manufacturer.

9.4.2.2 COLOR

For new carpet, the Government shall be provided with at least three color samples. The sample and color must be approved by EPA prior to installation. No substitutes may be made after sample selection. Use of solution dyed yarn shall be considered to minimize color fading and reduce water pollution..

9.4.2.3 INSTALLATION

Carpet must be installed in accordance with the approved manufacturer's instructions.

- In leased space, carpet shall be replaced at least once every 7 years during Government occupancy, or whenever backing or underlayment is exposed and/or there are noticeable variations in surface color or texture, whichever occurs first.
- Consider alternative methods of installation where feasible, including gridded glue down in low-traffic and low-moisture areas, and adhesive backing.

- Carpet replacement shall include the moving and returning-in-place of all furniture. Floor perimeters at partitions must have wood or carpet base. Any exceptions must be approved by the contracting officer.

- An additional 10 percent of the selected carpet tiles shall be provided by the contractor for the owner's own stock and replacement. These carpet tiles are not to be used during the warranty period.

- The off-gassing requirements in Chapter 5 of the *Safety Manual* shall be followed.

9.4.3 RESILIENT TILE

Unless otherwise indicated elsewhere in this document, all new resilient floor tile shall be 12 inch × 12 inch × 1/8-inch thick, shall have 35 percent to 40 percent reflectance, and shall be high density, meeting the requirements of Federal Specification SS-T-312, Type IV. Adhesives used to set tiles shall be low in volatile organic compounds (VOCs). Colors and patterns will be selected from three or more samples by the contracting officer or his or her duly appointed representative. If heavy duty, commercial grade floor tiles are specified, preference should be given to floor tiles made with recovered materials as designated in the CPG.

9.4.4 SEAMLESS VINYL FLOORING FOR LABORATORY FACILITIES

Seamless vinyl flooring for laboratories shall be chemical-resistant as manufactured by Tarket or Mipolan or an approved equal, and shall be coved 4 inches up the wall using the same material. Joints shall be chemically welded smooth without any grooves. Adhesive used to set the flooring shall be environmentally acceptable.

9.4.5 CERAMIC TILE FLOORING

Ceramic tile flooring shall be sealed in all grout areas. At least five color samples shall be incorporated into the color boards for selection and approval by the contracting officer (or his or her duly appointed representative).

9.4.6 SPECIAL FLOORING

Special floor-coating systems shall be troweled, jointless floor systems with slip-resistant top coatings which shall be waterproof and resistant to alkalies and acids. The special flooring system selected should be compatible with its intended use.

9.4.7 EXPOSED CONCRETE FLOORING

Steel trowel finish shall be used on exposed concrete floors that will not receive other finish. Exposed interior concrete floors shall be sealed with a penetrating-type solvent base or water-emulsion base unpigmented sealer containing a suitable type resin and no wax.

9.5 Paint

9.5.1 GENERAL

Before occupancy, all surfaces designated for painting must be newly painted with paint finish and colors acceptable to, and approved by, the contracting officer or that officer's duly appointed representative. The contracting officer or duly appointed representative shall be provided with color samples and color schemes, with their average surface reflectance value clearly identified, for selection. All paint must be low VOC latex (i.e., <3 grams/liter) unless specified otherwise. For interior and exterior latex paints, preference should be given to the use of reprocessed or consolidated latex paint, consistent with CPG guidance.

9.5.2 REFLECTANCE VALUES

Minimum average surface light reflectance values (LRV) that will be used as a base for the selection of interior colors are as follows:

- Ceiling: 80 percent.
- Walls: 70 percent.
- Floors: 30 percent.
- Furniture and equipment: 50 percent.
- Chalkboards: Not less than 15 percent nor more than 20 percent, as recommended in *American Standard Practice for School Lighting*, AIA No. 32F28.

Deviations from the above reflectance requirements are allowed for aesthetic treatment of such areas as conference rooms, lobbies, corridors, and executive offices. Surfaces shall also have a matte finish to prevent excessive brightness ratios and to minimize specular reflections.

9.5.3 WALL AND CEILING COLORS

Ceiling color can be extended from 1 to 3 feet down the walls, or to the level of the fixtures, to obtain up to 20 percent increase in illumination.

9.5.4 ACCENT AREAS

Up to 20 percent of wall surfaces may have reflectance values lower than those listed, for accent purposes, without being considered part of the average.

9.5.5 LEAD-BASED PAINT

Lead-based paint shall not be used in EPA facilities. Refer to Chapter 6 of the *Safety, Health, and Environmental Manual: Environmental Management Guidelines* (Volume 4 of the *EPA Facilities Manual*) for restrictions on the use of lead-based paint.

9.6 Window Covering

Permanent devices installed on the outside of buildings to control sunlight and provide security are discussed in subsection 8.3 of this Manual.

9.6.1 BLINDS

Window blinds may be either vertical or horizontal; nonmetallic slats or rollershades are required in laboratories. Color selection will be made by the EPA representative. The hardware and blind mechanisms in laboratories shall be made of acid-resistive materials.

9.6.2 BLACKOUT SHADES

Rooms requiring blackout capability shall be equipped with blackout shades. Shades should be a pre-engineered unit with a fiberglass-coated fabric shadecloth. They must have a noncorroding, concealed-variable adjustment mechanism, adjustable from 100 percent friction (static mode) with finite positions to 15 percent friction (dynamic mode) with only preselected positions.

9.6.3 DRAPERIES AND CURTAINS

All draperies, curtains, and similar hanging materials shall be of a noncombustible or flame-resistant fabric (chemically treated). Flame-resistant means that the fabric or films (e.g., thin plastic sheets or cellophane) must meet the performance criteria described in NFPA 701. In addition, draperies, curtains, and other window finishes shall be formaldehyde and chlorine free and shall meet the off-gassing criteria set forth in Chapter 5 of the *Safety Manual*.

END OF SECTION 9

Section 10 - Specialties

10.1 Magnetic, Liquid Chalk, Dry-Marker Boards and Tack Boards

Magnetic dry-marker boards (liquid chalk) shall be used except when the solvent markers used on these boards would affect operations undertaken in laboratories; chalk-type chalkboards shall not be used. Locations of magnetic dry-marker boards and tack boards shall be determined by the design professional in close coordination with the contracting officer's representative (COR).

10.2 Interior Signage Systems and Building Directory

10.2.1 GENERAL

All signage, identification, room numbering, and building directories shall comply with the requirements of the Americans with Disabilities Act (ADA).

10.2.2 DOOR IDENTIFICATION

Door identification shall be installed in approved locations adjacent to office entrances. The form of door identification must be approved by the COR. Toilet, stairway, and corridor doors must be identified by the international symbol of accessibility at a height of 54 to 66 inches above the floor; wherever possible, such identification should be mounted on the wall at the latch side of the door. Seldom-used doors to areas posing danger to the blind must have knurled or acceptable plastic-abrasive-coated handles. Tactile warning indicators shall not be used to identify exit stairs.

10.2.3 ROOM NUMBERING

A room-numbering and room-naming system is required for the identification of all spaces in the facility. Plans shall be submitted to the COR for review and approval before construction documentation begins.

10.2.4 BUILDING DIRECTORY

A wall-mounted, glass-enclosed directory with lock shall be provided at a conspicuous location in the lobby or entrance of the building. The directory shall be approximately 2 feet by 3 feet in size. The building directory shall be approved by the COR.

10.2.5 LABORATORY SIGNAGE

The laboratory signage should contain the room number, room name, occupants by name, hazardous chemicals within the laboratory, emergency telephone number, and special procedures in case of emergency.

10.3 Portable Fire Extinguishers

Portable fire extinguishers shall be provided and located within recessed cabinets, in accordance with National Fire Protection Association (NFPA) 10, Standard for Portable Fire Extinguishers. Portable fire extinguishers shall be provided on the basis of the classes of anticipated fires and the size and degree of hazard affecting the extinguishers' use. Portable fire extinguishers containing carbon tetrachloride or halon (chlorobromomethane) extinguishing agents shall not be used. As per requirements of PBS-P100, section 7.11, portable fire extinguishers and cabinets shall not be installed in common areas, general office or court space when the building is protected throughout with quick response sprinklers. Additionally, in office buildings protected throughout with quick response sprinklers, fire extinguishers shall only be installed in areas such as mechanical and elevator equipment areas, computer rooms, UPS rooms, generator rooms, and special hazard areas.

Fire extinguishers shall be approved by a nationally recognized testing laboratory and labeled to identify the listing and labeling organization and the fire test and performance standard that the fire extinguisher meets or exceeds. The minimum rating for a single Class A extinguisher shall be 2-A in low hazard or medium hazard areas and 4-A in high hazard areas. The minimum rating for a single Class B extinguisher shall be 10-B in low hazard area, 20-B in medium hazard areas and 80-B in high hazard areas.

10.3.1 FIRE EXTINGUISHER LOCATIONS

Portable fire extinguishers shall be provided in every laboratory room. It is good practice to also locate a fire extinguisher in the corridor outside the laboratory in addition to those located within the laboratory. In the other areas of the building or in non-laboratory buildings, the minimum number of fire extinguishers needed for protection shall be determined in accordance with NFPA 10, Chapter 3, Distribution of Extinguishers.

- Class A and D extinguishers shall be located so that the travel distance to the respective Class A and D hazard areas does not exceed 75 feet.

- Class B extinguishers shall be located so that the travel distance to the Class B hazard areas does not exceed 50 feet.

- Extinguishers with Class C ratings shall be located on the basis of the anticipated Class A or B hazard.

- One extinguisher may be installed to provide protection for several hazard areas provided that travel distances are not exceeded.

10.4 Laboratory Casework

10.4.1 GENERAL

Preferably, all laboratory casework and associated fume hoods required in the facility shall be the product of one manufacturer and shall be installed under the recommendations of that manufacturer. The laboratory casework shall meet the functional, aesthetic, flexibility, and maintenance needs of each user. Performance set forth herein shall establish minimum standards for design, performance, and function. Products that fail to meet these standards will not be considered.

10.4.1.1 MATERIALS

Unless noted otherwise, all surfaces shall be of stainless steel or another nonporous, durable, corrosion-resistant material. For rooms that do not require casework of metal construction, the casework materials shall be wood or approved plastic. Wood casework shall be from certified sustainable forests or recycled material. Hardware used for wood or plastic casework shall be epoxy coated. Plastic laminate or other similar facing materials, over wood or composite material, are permitted only when the laminate or surfacing material is certified by the manufacturer to be impervious to acids and other common laboratory solvents.

10.4.1.2 QUALITY

The laboratory casework that is subject to the above requirements shall have components, configuration, materials, finish, and performance (including performance on chemical and physical performance tests) comparable to cantilevered frame (C-frame) casework systems manufactured by Hamilton Industries and Kewaunee Scientific Equipment Corporation. Equipment manufactured by others is acceptable if the products are of equal performance and have similar appearance and construction, but only after approval by the contracting officer.

10.4.1.3 MODULAR DESIGN

Design of laboratory casework (cabinets, counters, fume hoods) should be coordinated and compatible. Basic laboratory casework systems shall be composed of modular dimensioned units of modern design consisting of a self-supporting steel frame capable of containing service piping and drain lines and permitting the attachment and/or support of various styles of countertops, sinks, cupsinks, and utility hoses and connections, independently from base cabinet assemblies. Support systems shall provide the flexibility and unlimited horizontal interchangeability of any or all cabinet sizes without removal of the working top or interference of immediate vertical legs, supports, brackets, or framing between cabinets. Fixed laboratory casework shall be similarly flexible. The design of fixed casework shall be approved by the COR.

10.4.1.4 SUPPORT CAPABILITY

The system shall support work surfaces and steel undercounter cabinets independent of one another. All components shall be self-supporting and essentially independent of the building structure. The system shall support sinks, service fittings, plumbing fixtures, and service and waste lines by utilizing pipe clamps. The assembly shall be designed and manufactured in such a manner that each linear foot of span between supporting elements, is capable of supporting a live load of 200 pounds per linear foot plus a dead load of 50 pounds per linear foot. In addition, it should be possible to place a concentrated load of 250 pounds on the front edge of the assembly at any point (assuming legs spaced at 6 feet on center) without causing the system to fail in its suspension or tip or deflect more than $^{3}/_{16}$ of an inch.

10.4.2 CABINET ASSEMBLIES

Cabinet assemblies shall be suspended from the support system with fastener devices mounted in front of the unit for attachment to the front rail and shall be designed so that removal of units can be easily accomplished by use of common hand tools. Such fastener devices shall be of forged or cast steel and shall be commercially cadmium plated. Filler panels shall be provided at exposed-to-view areas, between backs of cabinets and walls, between backs of cabinets at the end of the peninsula or island benches, and at knee openings, to allow for the maintenance of mechanical services.

10.4.3 BASE CABINETS

Casework shall be of a metal construction of slimline design and shall be built in accordance with the highest standards and practices of the metal casework industry. Superior quality casework shall be established by use of proper machinery, tools, dies, fixtures, and skilled workmanship so that the fit of doors and drawers allows vertical and horizontal openings of minimum tolerance. All units shall be of flush-front construction so that drawer and door faces are in the same plane as exterior case members. All units shall include label holders on all drawers and doors. Each unit shall be a completely welded structure and should not require additional parts such as applied panels at ends, backs, or bottom. Six-inch drawers are standard in the base drawer units. Unless otherwise noted in specific room data sheets, knee spaces shall be 3 feet in length and 29 inches in height.

10.4.4 WALL CABINETS

Upper wall cabinets shall be designed so that cabinets hang rigidly vertical without sag or tilt. The design professional shall be responsible for ensuring that proper reinforcement is installed at the walls to support the load of the cabinets and contents. Construction of wall cabinets shall be of similar to that of base cabinets; wall cabinets shall be modular in design and installation to permit immediate interchangeability of all wall cabinets and/or shelf units.

10.4.5 SHELVING

The following subsections provide information on reagent and adjustable shelving.

10.4.5.1 REAGENT SHELVES

Reagent shelves shall be 1-inch-thick plywood, faced on both sides with acid-resistant plastic laminate, with all exposed edges edge-banded in 3-millimeter ($^{1}/_{8}$-inch) thick polyvinyl chloride (PVC) or similar performing material.

10.4.5.2 ADJUSTABLE SHELVING

Adjustable shelving shall be 16-gauge steel shelving with hat-section reinforcing and shall be interchangeable with wall-hung cabinets. Shelving standards shall be double-slotted, 30 inches in length, mounted at a height of 54 inches above finished floor (measured to the bottom of the standard). Brackets shall be 16-gauge metal with three blade hooks and shall be screwed to each shelf.

10.4.6 VENTED STORAGE CABINETS

Vented acid/base storage cabinets shall be 3-foot-wide metal cabinets. The inner surfaces of the cabinet shall be factory coated to resist acid/base fumes and spills. One adjustable shelf shall be provided. Venting shall be as for vented chemical storage cabinets.

10.4.7 COUNTERTOPS

Countertop materials will vary depending on the intended use. The design professional shall be responsible for evaluating the requirements of the laboratories to determine what countertop material is most suitable for each specific application. The material used for the countertop shall also be used for back-splashes, side-splashes, and services ledge covers. Countertops adjacent to sinks shall have grooved drainboards. Casework along walls shall have a 4-inch-high backsplash.

10.4.7.1 PLASTIC LAMINATE

Chemically resistant plastic laminate countertops may be used in many applications where the use of extremely corrosive chemicals or large amounts of water is not expected.

10.4.7.2 EPOXY RESIN

Epoxy resin (water-based) countertops shall be utilized in laboratories or in areas where large quantities of water or extremely corrosive chemicals are being utilized on a routine basis. All joints shall be bonded with a highly chemical-resistant and corrosion-resistant cement having properties similar to those of the base material.

10.4.7.3 STAINLESS STEEL

Stainless steel countertops shall be used in special applications where sterile conditions are required (e.g., glassware washing areas, autoclave rooms), where there are controlled environmental temperatures (e.g., cold rooms, growth chambers), and where radioisotopes are being used.

10.4.8 LABORATORY FUME HOODS

Fume hoods shall be provided in all laboratories and laboratory support spaces where hazardous chemicals or other toxic materials are being utilized. The purpose of the laboratory fume hood is to prevent or minimize the escape of contaminants from the hood into the laboratory. The fume hood work surface shall be of recessed design so that spills can be effectively contained. The design professional shall be responsible for determining, with the users of the facility, types and sizes of fume hoods appropriate to their intended use. After the mechanical/laboratory fume hood exhaust systems have been installed, the testing, adjusting and balancing (TAB) has been completed, and the TAB Report has been approved by SHEMD, each laboratory fume hood shall be certified by the hood manufacturer or his qualified representative to be installed and functioning according to specifications. See Section 15, Mechanical Requirements, of this Manual for more specific requirements.

10.4.8.1 FUME HOOD LOCATION

Fume hoods must be located away from doors, pedestrian traffic, and duct work. The location of the hood shall be at the end of a room or bay, but not less than 1 foot from the corner, where the operator is essentially the only one who enters the zone of influence. A 5-foot minimum aisle width shall be maintained in front of fume hoods. It is good design practice not to have "dead-end" circulation patterns that may trap an individual in case of a laboratory accident. Further, hoods shall be placed in such a way that one hood cannot draw air from another hood.

10.4.9 ENVIRONMENTAL ROOMS

Environmental rooms shall be of modular, insulated panel construction, providing temperature and humidity control with specified setpoint control. Temperature requirements for individual rooms shall be appropriate to the rooms' intended use. Rooms shall be provided with emergency auxiliary power backup to allow 24-hour operation. All rooms involving laboratory procedures shall be ventilated. Fume hoods shall not be allowed in environmental rooms. The following should also be provided: remote air- or water-cooled dual-sequencing compressor, temperature and humidity recorders, high/low alarm, adjustable epoxy-coated wire shelving on wall supports or movable racks, and personnel emergency alarm.

END OF SECTION 10

Section 11 - Equipment

11.1 Design

Planning for equipment shall be integrated with the planning of architectural, structural, mechanical, and electrical systems. Equipment shall be arranged and organized to provide circulation, workflow, and maintenance clearances.

11.2 Catalog Cut Sheets

Appropriate catalog cut sheets shall be provided for all items of equipment. Each cut sheet shall have a logistical category and code. Each item shall be clearly identified if it has unique utility requirements, structural support needs, or space requirements.

11.3 Layout and Clearances

Equipment should be arranged to provide service clearances and maintenance access so that service and maintenance can be executed with minimum disruption to workspaces. When expansion is anticipated in a project, the design professional should ensure that some additional equipment can be added without disruption or reconfiguration of workflow.

11.4 Floor Preparation

Floor depressions shall be provided to accommodate items and design requirements, such as entrance walk-off grilles, cart washers, environmentally controlled room equipment, walk-in refrigerators, computer rooms, and any other appropriate spaces or items, except in laboratory spaces where future flexibility is a requirement.

11.5 Structural Support

Wall-partitioning systems for wall-hung equipment, wall-hung workstation storage, and toilet accessories shall be adequately reinforced. Ceiling support systems for service columns, hoist equipment, and other ceiling-mounted items shall be structurally braced. All fixed equipment shall be mounted to resist seismic forces in accordance with seismic levels defined for each applicable project.

11.6 Special Ventilation Requirements for Equipment

Control of ventilation for the employee working environment must be provided by the equipment supplier. All indoor air quality requirements shall be in accordance with Chapter 5 of the *Safety Manual*.

11.7 Equipment Specifications

Equipment specifications shall be developed for all equipment that does not have current guide specifications. All equipment specifications should permit procurement of the most current model of equipment through General Services Administration (GSA) services where possible. All equipment specifications should be developed to accommodate reputable vendors. Equipment specifications should discuss the scope of services to be provided by mechanical and electrical contractors installing Government-furnished equipment.

11.8 High-Technology Equipment

Project-specific guidance should be obtained on high-technology equipment. Design shall be in accordance with selection and guidance of the respective manufacturers.

11.9 Mechanical and Electrical Equipment

Refer to Sections 15 (Mechanical Requirements) and 16 (Electrical Requirements) of this Manual for information on mechanical and electrical equipment, respectively.

11.10 Equipment Consultants

Use of an equipment consultant is recommended for defining and specifying what research equipment must be procured. Such consultants shall also provide information on equipment during the design and construction document phases to assist in planning and documentation.

END OF SECTION 11

Section 12 - Furnishings

12.1 Furnishings

EPA requires that environmental evaluation be added to the criteria for furniture selection, considering topics such as VOC emissions, manufacturing practices, materials origination, recycled content and packing/shipping considerations. This enhanced consideration is a core value in EPA's Environmentally Preferable Purchasing program.

All major furniture items should consider the use of an environmental assessment of the manufacturing process and chamber-testing of the furniture emissions, following a strict protocol. The testing protocol, chain-of-custody requirements, packing and shipping instructions, and the manufacturng assessment instrument used for the EPA Headquarters project are available on EPA's web site, at www.epa.gov/greeningepa.

Furnishings are discussed in Chapter 6 of the *Space Planning and Acquisition Guidelines* (volume 1 of the *EPA Facilities Manual*). Additional information on "Green" specifications for furniture can be obtained from the Sustainable Facilities Practices Branch (SFPB). Sample copies of Green Rider provisions are available to assist in determining Green furnishings.

END OF SECTION 12

Section 13 - Special Construction

13.1 Noise Control

Noise levels in the different rooms of the facility should be in accordance with the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) handbook, *HVAC Systems and Applications*, Chapter 52 (Sound and Vibration Control). Proper schematic planning should isolate noise-sensitive areas from noise sources by separation with a nonsensitive buffer area. In addition, dedicated laboratory support spaces should be provided to isolate noise-producing equipment, such as centrifuges and vacuum pumps, from laboratories. In any instrument or laboratory space in which one or more fume hoods are used, the noise level should be 55 or less decibels of sound measured on an A-scale (dBA) but shall not exceed 70 dBA at the working position in front of the hood.

The combined noise resulting from several pieces of equipment shall not exceed 65 dBA when measured 3 feet from any piece of equipment. Noise generated from vibration by heating, ventilation, and air-conditioning (HVAC) systems may be minimized by several means: judicious equipment selection; limitation of fluid flow velocities; isolation of key mechanical, piping, and ducting systems; and other prudent engineering and architectural means.

13.1.1 VIBRATION ISOLATION

Vibration isolation systems should be provided on rotating mechanical equipment of greater than ½ horsepower (hp) (for equipment located within a critical area), greater than 5 hp (for other areas in the building), and greater than 10 hp (outside and within 200 feet of the building). Reciprocating equipment (other than emergency equipment) shall not be used. Vibrating equipment shall not be placed on top of buildings, unless no other locations are feasible. Vibrating equipment that must be mounted on the roof shall be placed directly over columns and on pads and springs to totally isolate the vibration from the building structure.

- Concrete inertia bases will be used with rotating mechanical equipment handling liquids (e.g., pumps) and with compressors. Steel frames will be used for air-handling equipment.

- Flexible pipe connectors (e.g., twin-sphere connectors) will be used on piping connecting to isolated equipment and where piping and ducting exit the mechanical room(s).

- Flexible duct connectors will be used in a manner similar to flexible piping connectors.

13.1.2 PIPING AND DUCTING SYSTEMS

Passive piping and ducting systems are defined as those that are at a great distance from their energy source and have low flow rates and/or infrequent use (examples of such systems are city water, gases, and waste water). Conversely, active piping systems are defined as those that are close to energy sources and can constitute a major vibration problem requiring isolation.

- Active piping and ducting shall be sized for economical flow velocities.

- Ducts that are less than 24 inches in diameter do not require isolation, provided that the flow velocities do not exceed 1,200 feet per minute. Ducting that does not meet this requirement shall be isolated.

- Active piping associated with HVAC (chilled water, condenser water, hot water, steam, and refrigerant piping) within mechanical rooms, or at least 50 feet (whichever distance is greater) from connected vibration-isolated equipment (e.g., chillers, pumps, air handlers) or from the ground, shall be isolated from the building structure; resilient penetration sleeves shall be used where this piping penetrates walls. Flexible piping connectors shall be used where the piping leaves the mechanical room. All active piping in the critical area having a diameter of 4 inches or less shall be isolated.

13.1.3 SOUND DAMPENING

Sound dampening features (acoustical treatment), preferably of rigid materials, shall be provided in instrument rooms so that the noise level does not exceed 55 dBa. If a hood is required in these rooms, the noise level shall not exceed 70 dBa at the face of the hood.

13.2 Fire Walls and Fire Barrier Walls

Fire walls must be structurally independent and have sufficient structural stability under fire conditions to allow collapse of construction on either side of the firewall without collapse of the fire wall itself. The wall is also required to allow collapse of the structure on one side without compromising the integrity of the structure on the opposite side of the fire wall. Fire walls differ from fire barrier walls, which do not require structural stability. Fire barrier walls may rely on the building structure for support. Refer to National Fire Protection Association (NFPA) 221 for specific criteria related to fire walls and fire barrier walls.

13.2.1 FIRE WALLS

Every fire wall shall be made of noncombustible material with the fire-resistance rating required by local codes for segregating the building into separate buildings or fire areas. Openings in fire walls shall be protected as noted in subsection 13.2.3 below. Unprotected windows are not allowed in fire walls.

13.2.2 FIRE BARRIER WALLS

Unless other fire-resistive construction is provided to create a complete enclosure on all sides, all fire barrier walls must extend from floor slab to floor slab or to roof deck. Openings in fire barrier walls shall be protected as noted in subsection 13.2.3 below.

13.2.3 OPENINGS

Openings in fire walls and fire barrier walls shall be protected with fire-rated components capable of maintaining the fire-resistive integrity of the wall. The minimum fire-resistance requirement for protection of openings in fire walls and fire barrier walls shall be the more restrictive of Chapter 8 of NFPA 101 (2000 edition) and the state building code. Greater fire resistance may be required by code requirements for specialized occupancies such as computer rooms and laboratories. Fire window assemblies are allowed in fire barrier walls with a 1-hour or lower fire-resistance rating. The maximum allowed glazing area in windows shall be the maximum area tested and shall be in accordance with NFPA 80. Refer to Chapter 2 of the *Safety Manual* for restrictions on utilities penetrating required fireproofing.

13.3 Vertical Openings and Shafts

Fire-resistance ratings for enclosures of vertical openings and shafts shall conform to the requirements in NFPA 101, Chapter 8. Openings into vertical openings and shafts shall be protected by fire doors or fire dampers as outlined in subsection 13.3.2 and in Chapter 2, Fire Life Safety, of the *Safety Manual*.

13.3.1 ATRIUMS

Atriums and other openings, where permitted by NFPA 101, NFPA 92, and the local building code, shall be protected in accordance with Chapter 8 of NFPA 101. In addition, exits shall be separately enclosed from the atrium. Access to exits is permitted to be within the atrium space.

13.3.2 SHAFTS

When telephone rooms, electrical closets, and similar spaces are located one above the other, the enclosure walls are considered to form a shaft, and protection shall be provided in accordance with the requirements of NFPA 101 and the local building code. Shafts shall not be installed between a structural member and the fireproofing for that member. If allowed by the local building code, all floor penetrations within telephone and electric closets can be sealed or otherwise grouted, in lieu of creating a shaft, to maintain the fire resistance of the floor assembly.

Structural members passing through a shaft shall be fireproofed separately from the shaft enclosure so that the entire structural member is protected as required by the model building codes. The fireproofing shall be of concrete, plaster, or other hard material that is resistant to mechanical damage and not subject to rusting or corrosion.

13.3.3 MONUMENTAL STAIRS

Large, open stairs shall be protected by one of three methods. If the stairs are not involved in the building exit requirements, they may extend one floor above and one floor below the main entrance lobby, provided that fire partitions and self-closing fire doors are installed at the upper and lower levels. Alternatively, they may be protected as a vertical opening in accordance with the requirements of Chapter 8 of NFPA 101 (2000 edition). If the stairs are part of the exit system, they must be protected as outlined in Chapter 7 of NFPA 101 (2000 edition).

13.3.4 ESCALATORS

Escalators shall be treated in the same manner as monumental stairs with the additional option of using curtain boards and sprinkler protection as detailed in NFPA 13.

13.3.5 PENETRATIONS

Openings around penetrations in vertical openings and shafts shall be fire-stopped as described in subsection 13.3.2 above.

13.4 Fire Protection

13.4.1 GENERAL

The decision to install sprinkler protection in the facility shall be based on NFPA 101, NFPA 45, the *Safety Manual*, state and local codes, and the project criteria, whichever is most stringent. All sprinkler systems shall comply with NFPA 13 and be approved by Factory Mutual or another nationally recognized insurance company. Special protection systems may be used to extinguish or control fire in easily ignited, fast-burning substances such as flammable liquids, some gases, and some chemicals. Such protection systems shall also be used to protect ordinary combustibles in certain high-value occupancies that are especially susceptible to damage. Special protection systems supplement automatic sprinklers as described by NFPA and shall not be used as a substitute for them except where water is not available for sprinkler protection. Halon systems shall not be used unless directed by the project criteria.

13.4.2 WATER SUPPLIES

Except as noted below, every building shall be provided, at a minimum, with a water supply that is available for use by fire department mobile pumping apparatus. The water supply shall normally be provided by fire hydrants suitable for firefighting apparatus and located within 5 feet of paved roadways. The hydrants shall be supplied from a dependable public or private water main system. Alternative water supplies shall be developed in accordance with NFPA 1142. Other water supplies shall be available to buildings where fire protection requires them. Fire protection water does not have to meet drinking water standards.

The water supply system shall provide ample water for each of the three types of fire protection water use: outside fire department hose streams from hydrants, small and large hose streams from inside-building standpipe or hose connections, and automatic sprinkler systems. The minimum requirements for each type of water use shall not be cumulative or additive and are determined as described below.

13.4.2.1 FIRE DEPARTMENT HOSE STREAMS

The hose stream required shall be determined by using the needed fire flow calculation method outlined in Section 300 of the Fire Suppression Rating Schedule of the Insurance Service Office. The needed fire flow shall be based on the fire areas of the building, not on the entire area of the building. The fire flow for the fire area requiring the greatest water flow shall be the needed fire flow for the building.

13.4.2.2 STANDPIPE HOSE STREAM

When standpipe systems are provided or required, the minimum water supply shall be in accordance with NFPA 14 and the local building code and shall be based on the number of standpipe risers provided in the building or in each fire area.

13.4.2.3 AUTOMATIC SPRINKLERS

The minimum flow required to meet the needs of the automatic sprinkler system shall be determined by hydraulic calculations as required for sprinkler system designs. The water supply requirements shall include all sprinkler flow and required hose stream allowances outlined in NFPA 13.

13.4.3 SIZE AND ZONING

The sprinkler system main shall be sized to meet the fire flow and pressure requirements set by the local authority. Fire pump(s) shall be provided, if needed, and shall be installed in a separate room along with the sprinkler system main valves. Sprinkler system protection zones shall have the same boundaries as the fire alarm system fire zones. Each sprinkler system protection zone shall be equipped with electrically supervised control valves and water flow alarm switches connected to the fire alarm system.

13.4.4 SYSTEMS

Fire protection systems must meet the following requirements.

13.4.4.1 AUTOMATIC SPRINKLER PROTECTION

Automatic sprinkler protection shall be provided in all new EPA facilities. All sprinkler systems shall be hydraulically calculated in accordance with NFPA 13. All design documents, including the hydraulic calculations, must be maintained at the building to facilitate future modifications of the sprinkler system An analysis shall be performed to justify new facilities with no sprinkler protection. The provision of sprinkler protection (when not required by another code or standard) shall not be used as a basis for reducing other levels of protection provided for that facility. However, where a code or standard allows alternatives based on the provision of sprinklers, as in NFPA 101, the alternatives allowed for sprinklered space may be applied.

Existing facilities shall be provided with sprinkler protection under the following circumstances:

- In major modifications to existing laboratories that use chemicals, flammable liquids, or explosive materials.
- Throughout all floors of any building where EPA occupancy is 75 feet high or higher. The height shall be measured from the lowest point of fire department access to the floor level of the highest occupiable story.
- Throughout occupancies exceeding the area or height limitations allowed by the local building code.
- In all areas below grade that meet the definition of “windowless” in local code.
- In all areas that contain a high-severity occupancy as defined by the General Services Administration (GSA).

- Throughout windowless buildings, windowless floors of buildings, and windowless areas that exceed the allowable limits of the local building code.
- In cooling towers of combustible construction under the conditions described in subsection 15.5.5.
- In any location where the maximum fire potential of the occupancy exceeds the fire-resistance capabilities of exposed live-load-bearing structural elements (e.g., when a flammable-liquids operation is moved into a former office area).
- Throughout open-plan office space that has a fuel load in excess of 6 pounds per square foot.
- Throughout electronic equipment operation areas, including data storage areas. On/off type sprinkler heads and sprinkler guards may be used to minimize water damage in these areas.

13.4.4.2 WET PIPE

Sprinkler systems shall normally be wet pipe. Hydraulic designs shall be performed for all systems.

13.4.4.3 DRY PIPE

In unheated areas or other areas subject to freezing temperatures, dry-pipe systems shall be provided. Because of the time delays associated with the release of the air in the system, water demands for dry-pipe systems shall be computed on the basis of areas 30 percent greater than those used to computer demands for comparable wet-pipe systems. Where the unheated area is small, it may be cost-effective to install an antifreeze system or a small dry-pipe system supplied from the wet-pipe system in the main heated area.

13.4.4.4 PREACTION

A preaction system shall be used where it is particularly important to prevent the accidental discharge of water. Each laboratory room must be provided with a preaction system with an individual isolation valve. The need for a preaction system shall be determined on the basis of review by, and recommendation of, a AEAMB professional fire protection engineer. The detection system chosen to activate the preaction valve shall have a high reliability and shall be equipment with a separate alarm/supervisory signal to indicate status. The detection system must be designed to be more sensitive than the closed sprinklers in the preaction system but should not be so sensitive as to cause false alarms and unnecessary actuation of the preaction valve.

13.4.4.5 DELUGE

For extra hazard areas and specific hard-to-extinguish fuels such as explosives and pyrophoric metals, a deluge system with open sprinkler heads may be used to wet down the entire protected area simultaneously. Deluge systems shall comply with NFPA 13. If quick response is required, deluge system piping may be primed with water. The nozzles must be provided with blow-off caps for water-filled deluge systems.

13.4.4.6 SELF-RESTORING

Self-restoring sprinkler systems, such as the on/off multicycle system or systems using individual on/off sprinkler heads, shall be considered where the water from sprinklers will become contaminated by contact with room contents, where there is a concern about water damage, or where water supply or storage volume is marginal.

13.4.4.7 QUICK RESPONSE

Quick-response sprinklers must be used in new installations except where prohibited. Other specialized automatic sprinklers, such as large drop, early-suppression fast-response, or extended-coverage heads, are acceptable for use in sprinkler systems. The use of specialized sprinklers is appropriate when a higher level of protection is desired or an equivalent level of protection is necessary to compensate for failure to meet other code requirements. Use of specialized sprinkler heads should be limited to applications for which they have been specifically listed (e.g., UL, FM).

13.4.4.8 WATER SPRAY

Installation of water spray systems shall comply with NFPA 15.

13.4.4.9 CARBON DIOXIDE

Agent quantity requirements and installation procedures shall comply with NFPA 12.

13.4.4.10 DRY CHEMICAL

Systems shall comply with NFPA 17.

- Design requirements. Systems shall be designed in accordance with NFPA 17 and NFPA 96. Discharge of dry chemical shall actuate a pressure switch connected to an alarm in the building fire alarm system. Refer to Section 16, Electrical Requirements, of this Manual for fire alarm requirements.

- Acceptance tests. After installation, all mechanical and electrical equipment shall be tested to ensure correct operation and function. When all necessary corrections have been made, a full discharge test shall be conducted. Plastic or cotton bags shall be attached to each individual nozzle, and the system activated. Cooking appliance nozzles must discharge at least 2 pounds of the agent, and duct or plenum nozzles must discharge at least 5 pounds of the agent. Preengineered systems that fail to discharge these amounts will be considered unsatisfactory.

13.4.4.11 FOAM

Foam systems shall comply with NFPA 11, NFPA 11A, NFPA 16, NFPA 16A, and NFPA 409.

13.4.4.12 STANDPIPES AND HOSE SYSTEMS

NFPA 45 requires the installation of standpipe and hose systems in all laboratory buildings that are two or more stories above or below the grade level. Installation of standpipe systems shall comply with NFPA 14. If local building fire code requirements dictate the installation of hose systems, hose systems shall comply with NFPA 14 and shall be pressure tested annually in accordance with the methods presented in NFPA 1962.

13.4.4.13 PORTABLE FIRE EXTINGUISHERS

Portable fire extinguishers shall comply with NFPA 10 except that halon extinguishers shall not be placed in any EPA facility. See Section 10, Specialties, of this Manual for more information on portable fire extinguishers.

13.4.4.14 HALON-1301 FIRE-EXTINGUISHING SYSTEMS

Fire protection systems that contain halon-1301 (CF_3Br, a halogenated hydrocarbon) shall not be installed in new EPA facilities. Existing systems that use halon-1301 should be removed from service in accordance with Title VI of the 1990 Clean Air Act Amendments. The hardware may be left in place in anticipation of an environmentally acceptable replacement. This policy applies to both fixed and portable systems. The halon recovered from systems should be made available through the Halon Recycling Corporation (1-800-258-1283). Refer to the *Environmental Management Guidelines* for information on removal of halon systems from EPA-owned or -leased facilities. Refer also to the list of acceptable halon substitutes approved under the significant new alternatives policy (SNAP) (published by EPA's Office of Air and Radiation Stratospheric Protection Division).

13.4.4.15 GASEOUS FIRE-EXTINGUISHING SYSTEMS

While carbon dioxide systems are allowed in normally occupied spaces, it is recommended that their use as a total flooding agent be limited to areas that are usually not occupied. Any carbon dioxide automatic extinguishing system that is to be used in usually occupied spaces must be reviewed and approved by AEAMB and SHEMD and must meet the design requirements of NFPA 12 and 29 CFR §1910.162(b)(5). A number of clean-agent, gaseous fire-extinguishing systems are becoming available as an alternative to halon and carbon dioxide systems, among these FM-200 and Inergen. Because of the unique nature and limited approvals for these new systems, any design and installation shall be certified by a licensed professional engineer in the state and approved by the authority having jurisdiction. The certification must include a detailed analysis of the hazards to be protected against; any limitations on, or exclusions of, hazardous chemicals that may be protected against by the design; and documentation to support the design concentration of the agent. The installation of such a system shall meet the requirements described below.

- Design requirements. Systems shall be designed in accordance with NFPA 2001 and other applicable standards for the hazard to be protected against. Discharge of a system shall actuate a pressure switch or other device connected to initiate an alarm in the building fire alarm system. Refer to Section 16, Electrical Requirements, of this Manual for fire alarm requirements.

- Acceptance tests. After installation, all mechanical and electrical equipment shall be tested to ensure correct operation and function. All approval or acceptance testing shall be performed in accordance with Section 4-7 of NFPA 2001.

13.4.4.16 WET CHEMICAL SYSTEMS

Wet chemical systems are generally pre-engineered and are primarily used to protect exhaust hoods, plenums, ducts and associated cooking equipment such as deep fat fryers and grills. Refer to NFPA 17A for technical requirements, applications, and specifications.

13.4.5 OPERATION

Operation and maintenance instructions and system layouts shall be posted at the control equipment. All personnel who may be expected to inspect, test, maintain, or operate fire protection apparatus shall be thoroughly trained and kept trained in the functions they are expected to perform.

13.4.6 CODES

In addition to meeting the code requirements mentioned in the above subsections, the design shall be approved by the local authority having jurisdiction over the project.

END OF SECTION 13

Section 14 - Conveying Systems

14.1 General

Elevators, dumbwaiters, escalators, and moving walks shall be in accordance with American National Standards Institute (ANSI) Standard A17.1. Other requirements are described below.

14.2 Elevators

14.2.1 ELEVATOR RECALL

All automatic elevators having a travel distance of 25 feet or more shall be recalled when any fire alarm–initiating device, such as elevator lobby smoke detectors, manual fire alarm stations, or sprinkler system waterflow switches, is activated. All elevators must be recalled when the recall system is activated. Smoke detectors other than those required by ANSI A17.1 shall not initiate automatic elevator recall.

14.2.2 SMOKE DETECTORS

Smoke detectors shall be provided for every elevator lobby, including the main lobby. Smoke detectors that activate the automatic elevator recall are also required in the elevator machine rooms. Elevator lobby smoke detectors should not initiate the building fire alarm system but shall send an alarm to the fire department or central station service and shall activate the elevator recall system.

14.2.3 CAPTURE FLOOR

An alternate capture floor shall be provided in accordance with Rule 211.3b(2) of ANSI A17.1. Activation of an alarm-initiating device on the main capture floor shall return the elevators to the alternate capture floor.

14.2.4 SIGNAGE

Signs must be placed in the elevator lobbies next to all elevators to inform occupants not to use the elevators if there is a fire.

14.2.5 CHEMICAL TRANSPORT USE

If elevators are used to transport chemicals, provisions shall be made to ensure that nonlaboratory personnel and space (administrative or business occupancies) are not exposed to or contaminated by chemical substances. For example, chemicals must be packaged in accordance with U.S. Department of Transportation (DOT) specifications, or an alternative route of transport must be provided. This alternative route may include an elevator opening into a vestibule separate from administrative or business occupancies, a multiple-door elevator entering into a laboratory, separate dumbwaiters, or alternate corridors or routes. A combination of these options can be used to achieve this goal.

14.3 Escalators

Escalators shall be treated in the same manner as monumental stairs with an additional option of providing curtain boards and sprinkler protection as detailed in National Fire Protection Association (NFPA) 13.

END OF SECTION 14

Section 15 - Mechanical Requirements

15.1 General

The design professional shall be responsible for ensuring that all mechanical systems conform to the requirements of this section and that all systems are installed and operating in accordance with all governing codes, ordinances, and regulations; the most current edition of applicable publications; and as set forth below. The design professional is responsible for the design of all mains, lines, meters, and other mechanical components required for utility services. The building mechanical systems shall provide a safe and suitable environment both for occupants and for functional operation of the facility, and shall meet EPA's energy conservation and atmospheric emissions goals.

15.2 References

All work discussed in this section shall comply with all applicable federal, state, city, and local codes, regulations, ordinances, publications, and manuals. When codes or publications conflict, the most stringent standard shall govern. Unless otherwise specified in this Manual or approved by the Architecture, Engineering and Asset Management Branch (AEAMB) and the Safety, Health and Environmental Management Division (SHEMD), all mechanical system installations shall conform to the standards listed below:

- Installation of Oil Burning Equipment (NFPA 31)
- Stationary Combustion Engines and Gas Turbines (NFPA 37)
- Fire Protection for Laboratories Using Chemicals (NFPA 45)
- National Fuel Gas Code (NFPA 54)
- Storage and Handling of Liquefied Petroleum Gases (NFPA 58)
- Storage and Handling of Liquefied Natural Gas (NFPA 59A)
- Protection of Electronic Computer/Data Processing Equipment (NFPA 75)
- Standard for the Installation of Air-Conditioning and Ventilating Systems (NFPA 90A)
- Installation of Exhaust Systems for Air Conveying of Materials (NFPA 91)
- Smoke Control Systems (NFPA 92A)
- Ventilation Control and Fire Protection of Commercial Cooking Operations (NFPA 96)
- Water Cooling Towers (NFPA 214)
- Elevators, Dumbwaiters, Escalators, and Moving Walks (ANSI A17.1)
- Ventilation for Acceptable Indoor Air Quality (ANSI/ASHRAE 62)
- Emergency Eyewash and Shower Equipment (ANSI Z358.1)
- Fundamentals Governing the Design and Operation of Local Exhaust Systems (ANSI/American Industrial Hygiene Association (AIHA) Z9.2)
- Laboratory Ventilation (ANSI/ASHRAE Z9.5)
- Protecting Building Environment from Airborne Chemical, Biological, or Radiological Attacks (OHHS/NIOSH Publication 2002-139)
- *Procedures for Certifying Laboratory Fume Hoods To Meet EPA Standards*
- Safety Code for Mechanical Refrigeration (ANSI/ASHRAE 15)
- Method for Testing Performance of Laboratory Fume Hoods (ANSI/ASHRAE 110)
- *Building Air Quality: EPA Guide for Building Owners and Facility Managers*, EPA/400/1-91/033 or December 1991
- *Industrial Ventilation*: *A Manual of Recommended Practice*, American Conference of Government Industrial Hygienists (ACGIH)
- *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*, National Research Council, 1995

- National Sanitation Foundation (NSF) standard 49 for Biohazard Safety Cabinets.
- NSF standard 61 Drinking Water System Components.

15.3 Heating, Ventilation, and Air-Conditioning Design Criteria

A heating, ventilation and air-conditioning (HVAC) system that will satisfy the requirements indicated in this document shall be provided.

15.3.1 GENERAL

Building HVAC systems and subsystems shall be evaluated, and major HVAC equipment components shall be selected, on the basis of a consideration of health and safety requirements, occupant comfort, attributed atmospheric emissions, initial costs, operating costs, and maintenance costs. A life cycle cost analysis (LCCA) shall be performed using the National Institute of Standards and Technology (NIST) Handbook 135 "Life-Cycle Costing Manual for the Federal Energy Management Program" to select the most cost-effective HVAC system.

15.3.2 VENTILATION REQUIREMENTS

Indoor space shall meet the EPA National Ambient Air Quality Standards and the ventilation rates established in ASHRAE 62-2001. Design air quantities and transport velocities shall be calculated according to the methods prescribed in the ASHRAE *Handbook of HVAC Systems and Equipment*, the ASHRAE *Applications Handbook*, and the ACGIH *Industrial Ventilation* manual.

15.3.2.1 LABORATORY VENTILATION REQUIREMENTS

Laboratories must comply with unique ventilation requirements in accordance with the latest version of ANSI/AIHA Z9.5 and NFPA 45. The HVAC system for the sections of the laboratory building (including corridors) where the laboratory and laboratory support rooms are located shall be designed with 100 percent outside air ventilation systems with exhaust through hoods where hoods are used. These sections of the laboratory building, as well as the hazardous chemical storage building, shall have an independent air handling unit(s). Under no circumstances will the air supplied to any laboratory space be recirculated to any other space. HVAC systems should be continuously operational 24 hours a day, 7 days a week, summer and winter. The general exhaust and special instrument canopy hoods in these sections and in the hazardous chemical storage building shall be constant volume at all times; the only exceptions are to accommodate variable air volume (VAV) systems or two-flow (night setback) systems.

Minimum airflow requirement to be maintained in a laboratory is 25 cfm per square foot of laboratory fume hood (LFH) work surface with the sash closed or four air changes per hour for an unoccupied laboratory during night time, weekend or holiday setback, or calculated to prevent concentration of volatile vapors at or above 25 percent of their lower flammable/explosive limit (LEL) within the hood; and not less than eight air changes per hour during occupied hours. Specifications for controls and monitoring devices for exhaust and air-handling units should be consistent with these minimum airflow requirements. The exhaust requirements of LFHs and other exhaust devices, as well as the temperature and humidity requirements, shall override laboratory minimum air changes per hour.

Laboratory spaces shall be designed to maintain a pressurization level relative to other common spaces that is appropriate for the type of work performed in each laboratory and is negative to the laboratory corridor and non-laboratory spaces. Levels of pressurization shall be project specific.

15.3.2.2 ADDITIONAL SPECIAL VENTILATION REQUIREMENTS

All processes, operations, or other situations that present the possibility of hazardous accumulation of combustible or explosive vapors, dust, fumes, or other airborne substances shall be provided with ventilation in accordance with NFPA 91 and NFPA 45 and shall be 100 percent exhausted to atmosphere outside the building. To avoid re-entrainment, design for exhaust systems shall conform to ASHRAE 52-76 and ACGIH's *Industrial Ventilation*. Project criteria shall indicate other areas of nonrecirculation. Air from adjacent spaces can be used as the ventilation supply air for the 100 percent exhausted spaces, as long as:

- Ventilation by this method does not violate any requirements of ANSI Z9.5, NFPA 45, NFPA 90A, or NFPA 101 or special space pressurization requirements.

- The air supplied is not potentially more hazardous than the air from the space being exhausted.

- Adjacent spaces are not laboratory or specialty spaces requiring once-through ventilation.

In addition, the following spaces have special ventilation considerations:

- Restrooms, janitor closets, garbage rooms, and other malodorous spaces shall be exhausted to atmosphere outside the building at a rate of not less than 50 cfm per toilet or urinal, and as specified in ASHRAE 62 or in local building codes, whichever is more stringent, regardless of any other calculated ventilation requirements.

- Commercial cooking equipment used in processes that produce smoke or grease shall be designed and protected in accordance with NFPA 96. Any insulation shall be of noncombustible materials. If other utilities are included in a vertical shaft with the grease duct, they shall not be insulated or lined with combustible materials.

- Mechanical and electrical equipment rooms shall be exhausted so that room temperature does not exceed National Electrical Manufacturers Association (NEMA) equipment ratings. The project criteria shall establish the space temperature limits. Where mechanical ventilation cannot maintain a satisfactory environment, evaporative cooling systems (indirect evaporative cooling for electrical rooms) or other mechanical cooling systems shall be provided. Exhaust air openings should be located adjacent to heat-producing equipment to minimize ambient thermal loads. Thermostatic controls shall be used to operate the ventilation and exhaust systems.

- Equipment rooms containing refrigeration equipment shall be ventilated in accordance with ASHRAE standard 15. For all equipment rooms with fuel-burning appliances or equipment, combustion air for these appliances and this equipment shall be drawn directly from the outside, in accordance with the International Building Code, National Fire Protection Association (NFPA) codes, and the ASHRAE Guide and Data Books.

15.3.3 EQUIPMENT DESIGN TEMPERATURES

15.3.3.1 INSIDE DESIGN TEMPERATURES

Environmental design temperatures and relative humidity for special space uses other than those listed here shall be designated in the project criteria. The design temperatures shall be 5 degrees Fahrenheit (°F) lower for cooling, and 5°F higher for heating, than the required operating temperature.

When space cooling is required, the inside design temperature for maintaining personnel comfort shall be 70°F, dry bulb (db), unless otherwise indicated in project criteria. The relative humidity shall be 50 percent. Summer humidification shall not be provided for personnel comfort. Cooling systems shall be designed to maintain the relative humidity conditions of space through the normal cooling process and should not have controls that limit the maximum relative humidity unless system type or project-specific criteria dictate.

The inside design wintertime temperature for personnel comfort shall be 72°F db unless otherwise indicated here or directed by other project-specific criteria. All storage areas shall have a minimum temperature of 40°F to prevent freezing. Except where it can be substantiated from records or engineering computations that the inside relative humidity will be less than 30 percent, winter humidification for personnel comfort and health shall not be provided. Where such a condition has been substantiated, a design relative humidity of 30 percent shall be used in establishing minimum requirements for humidification equipment.

15.3.3.2 OUTSIDE DESIGN TEMPERATURES

The HVAC system equipment shall be designed by using the outside design temperatures shown in Table 15.3.3.2, Outside Design Conditions, for the particular application. The percentages of dry bulb (db) and wet bulb (wb) temperatures are derived from the sources of tabulated weather data described below. When data for a particular location are not listed, design conditions shall be estimated from data available at nearby weather stations or by interpolation between values from stations, taking into account elevation and other local conditions affecting design data. Weather data for use in sizing HVAC equipment shall be obtained from the local weather station and/or the ASHRAE *Handbook of Fundamentals*.

Table 15.3.3.2 Outside Design Conditions

Winter	Summer	Application
99% to 99.6% db	1% to 0.4% db and mean coincident wb	Process, laboratory, and other uses where close temperature and humidity control is required by project criteria
97.5 to 99% db	2.5 to 1.0% db and mean coincident wb	Personnel comfort systems
__	1% wb	Cooling towers* and research, technical-type systems
__	1% db plus 5EF	Air-cooled condensers*

*Temperature should be verified by reviewing actual site conditions.

15.3.3.3 EVAPORATIVE/ADIABATIC COOLING

In locations where a wide variation exists between the dry bulb and wet bulb temperatures for extended periods of time, evaporative/adiabatic cooling shall be considered for the applications listed below. Selection of cooler types shall depend on system configuration, user experience, and LCCA. All evaporative coolers shall maintain a positive water-bleed and water-makeup system for control of mineral buildup.

Applications for which evaporating adiabatic cooling are considered include warehouses, shops that do not require close (within 5°F plus or minus) temperature control, nonresidential-size kitchens, makeup air ventilation units, and mechanical equipment spaces.

Air duct design, number and location of coolers, and relief of the higher rate of air supply to the atmosphere shall be considered as means of ensuring a satisfactory operating system. Multistage evaporative cooling systems shall also be considered.

Indoor design dry bulb temperatures for spaces that are air-conditioned by adiabatic cooling systems shall be as specified in project-specific criteria. Design operating efficiency of adiabatic cooling equipment shall be at least 70 percent. System-installed capacity shall be based on the peak design cooling load for the air-conditioned space. An arbitrary air-change rate shall not be used for design airflow. Adiabatic cooler specifications shall be stated in terms of the air capacity, the entering ambient dry and wet bulb temperatures, and the leaving dry bulb temperature.

15.3.4 EQUIPMENT SIZING

HVAC equipment shall be sized to satisfy the building and cooling load requirements and to meet all equipment design and selection criteria contained in the ASHRAE *Fundamentals, HVAC Systems and Equipment, HVAC Applications,* and *Refrigeration* handbooks. The capacity of central heating, refrigeration, and ventilation equipment shall be set for the peak block building or the maximum simultaneous zone heating and cooling design loads and in accordance with the *ASHRAE Handbook of Fundamentals*. The equipment shall not be sized for future additional capacity or to provide redundancy unless indicated in project-specific criteria. Individual zone equipment shall be sized according to the peak zone load.

15.3.5 LOAD CALCULATIONS

Load calculations shall be based on data and procedures outlined in the ASHRAE handbooks and shall be in accordance with the conditions specified in this Manual. Load calculations may be performed manually or by a nationally recognized computer-based load program. Specialty programs that are not recognized must be approved by the contracting officer prior to use. If a separate auxiliary air system is provided, the auxiliary air must be heated and cooled to within the room dry bulb temperature. Auxiliary air shall not exceed 70 percent of total fume hood exhaust requirements.

15.3.6 WASTE HEAT RECOVERY

Energy conservation and waste heat recovery systems shall be considered and designed according to the procedures outlined in specific chapters of the ASHRAE *Fundamentals, Systems and Equipment, Applications*, and *Refrigeration* handbooks, and the Sheet Metal and Air-Conditioning Contractors National Association (SMACNA) *Energy Recovery Equipment and Systems Manual.* The following types of heat-recovery methods and systems shall be considered for incorporation into the building HVAC system design where appropriate.

- Use of heat pipe or coil runaround systems for heating and air-conditioning air-handling systems. Use of rotary heat wheel heat exchange is not permitted in laboratory fume hood, laboratory, or laboratory support area exhaust systems. Rotary heat wheels may be used in administrative area exhaust systems.

- Recovery of rejected heat from the condenser systems of central station cooling equipment for use in heating the remainder of the building (when the central station cooling equipment must operate during the heating season to cool computer rooms or high internal gain areas or to meet process requirements).

- Use of exhaust heat from the condenser systems of continuously operated refrigeration equipment for space heating or domestic hot-water heating.

- Use of a free cooling system that uses cooling tower water (water-side economizer) when air-side economizer systems are not feasible.

- Use of a heat pump run-around loop.

15.3.7 ENERGY EFFICIENCY

After a careful study of the facility’s requirements as well as of the day-to-day operation of its various departments has been made, systems shall be designed that meet the operating requirements in an energy-efficient manner. The local utility companies shall be contacted to evaluate the attributed atmospheric emissions and the system dollar credits for load shifting to off-peak times. The health and safety aspects of the operation must be given first priority, and they cannot be relaxed or traded off for greater efficiency.

15.4 Automatic Control Systems

15.4.1 GENERAL

This subsection covers automatic temperature and humidity controls, space pressurization controls, safety controls, and energy monitoring and central supervisory control systems. A complete automatic control system shall be designed by an HVAC controls design engineer with experience in designing systems of this type and complexity. A commissioning plan shall be submitted to and approved by EPA prior to the commissioning of the control system.

The final product shall be a complete, reliable, fully functional, maintainable, fully integrated, addressable, control system that has been properly designed, installed, and commissioned. In existing facilities, the design shall be integrated and interfaced into the existing control system so that the new equipment and conditions can be controlled and monitored similar to the existing controlled equipment.

15.4.1.1 TECHNICAL REQUIREMENTS

The control system shall be a direct digital control (DDC) system reflecting the latest technology that has been widely accepted by the control industry. DDC systems shall be electric/electronic only. Pneumatics shall not be allowed except in instances when the existing controls absolutely require that the new controls be pneumatic. The system shall be complete and suitable for the HVAC systems to be installed. The DDC system shall be compatible with any existing systems in the facility or shall be able to completely and seamlessly interface with the existing central control and monitoring system (CCMS) network. All control points, including the VAV controllers, shall be fully compatible with the CCMS, allowing complete monitoring, control, and setpoint adjustment of all points and VAV terminal unit controllers from the CCMS host. Outside air quantity to each air handling unit shall be automatically controlled at a volume to meet the requirements of ASHRAE Standard 62-2001. Typical points to be monitored and controlled include:

- Air Handling Units
    - Leaving air temperature
    - Entering air temperature
    - Entering chilled water temperature
    - Leaving chilled water temperature
    - Entering hot water temperature
    - Leaving hot water temperature
    - Temperature and humidity in each zone
    - Fan speed indication
    - Filter differential pressure
    - Supply air quantity
    - Outside air quantity

- Central Plant
    - Chiller on-off (each chiller)
    - Chilled water temperature in and out
    - Chiller status
    - Boiler on-off (each boiler)
    - Hot water temperature in and out
    - Boiler status
    - Steam-HW heat exchanger, water temperature in and out
    - Pump on-off indication, each pump
    - Cooling Tower fan speed
    - Condenser water temperature in and out
    - Steam pressure and temperature

- Variable Air Volume Zones (through VAV unit controller)
    - Zone temperature
    - Zone primary air flowrate (supply and exhaust volumes, CFM)
    - Zone temperature setpoint

- Alarm Print Outs
    - Chiller failure to start
    - Air handling unit fan failure
    - Zone space temperature rise to 5 degrees (F) above set point
    - Chilled water rise 5 degrees above set point
    - Hot water fall 5 degrees below set point
    - Zone RH 5% above set point
    - Pump failure.
    - Water on Floor of Mechanical Room
    - Laboratory fume hood sash position and hood alarm condition

- Points to be Controlled:
    - Start/stop chillers/chilled water pumps
    - Reset chilled water temperature
    - Start/stop boilers/hot water pumps
    - Reset hot water temperature
    - Start/stop air handling units
    - Start/stop exhaust and supply fans
    - Setpoint adjust - all controllers with setpoints
    - Enable/disable economizer cycles
    - Setpoint adjust - all VAV zone

15.4.1.2 CODES AND STANDARDS

The following codes and standards shall be referenced as applicable:

- ASHRAE 135-1995: BACnet - A Data Communication Protocol for Building Automation and Control Networks. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1995 including Addendums A through E
- UL 916, Energy Management Systems
- NEMA 250, Enclosure for Electrical Equipment
- NEMA ICS 1: General Standards for Industrial Controls
- NFPA 45, Fire Protection for Laboratories Using Chemicals
- NFPA 90A, Standard for the Installation of Air-Conditioning and Ventilating Systems (where applicable to controls and control sequences)
- NFPA 70, National Electrical Code (NEC).

15.4.1.3 CONTROL SYSTEM SUBMISSION

The design submission shall include complete control system drawings, complete technical specifications, and commissioning procedures for each control system. As a minimum, the following documentation shall be required for review by proper EPA officials:

<u>HVAC Control System Drawings</u>: Each control system element on a drawing shall have a unique identifier. The HVAC control system drawings shall be delivered together as a complete submittal.

HVAC control system drawings shall include the following: drawing index, HVAC control system legend, valve schedule, damper schedule, control system schematic and equipment schedule, sequence of operation and data terminal strip layout, control loop wiring diagrams, motor starter and relay wiring diagram, communication network and block diagram, DDC panel installation and block diagram.

- The HVAC control system drawing index shall show the name and number of the building, state or other similar designation, and country. The HVAC control system legend shall show generic symbols and the name of devices shown on the HVAC control system drawings.

- The valve schedule shall include each valve's unique identifier, size, flow coefficient Cv, pressure drop at specified flow rate, spring range, actuator size, close-off pressure data, dimensions, and access and clearance requirements data.

- The damper schedule shall contain each damper's and each actuator's identifier, nominal and actual sizes, orientation of axis and frame, direction of blade rotation, locations of actuators and damper end switches, arrangement of sections in multi-section dampers, and methods of connecting dampers, actuators, and linkages. The damper schedule shall include the maximum leakage rate at the operating static-pressure differential. The damper schedule shall contain actuator selection data supported by calculations of the torque required to move and seal the dampers, access and clearance requirements.

- The HVAC control system schematics shall show all control and mechanical devices associated with the HVAC system. A system schematic drawing shall be submitted for each HVAC system.

- The HVAC control system equipment schedule shall be in the form shown. All devices shown on the drawings having unique identifiers shall be referenced in the equipment schedule. An equipment schedule shall be submitted for each HVAC system.

- Sequences of operation shall be submitted for each HVAC control system including each type of terminal unit control system. A complete sequence of operation shall be included on the drawings along with a schematic control diagram for each typical system. The sequence of operation and schematic control diagrams shall specifically cover the following items and others as the project requires.

  1) Refrigeration compressor control
  2) Refrigeration system protective devices
  3) Chilled, DX and hot water control
  4) Water coil or evaporator control, temperature and/or humidity as required
  5) Cooling tor or air-cooled condenser control
  6) Air handling unit control with protective devices
  7) Individual unit control
  8) Motor interlocks with system, starting and stopping instruction
  9) All thermostat, humidistat, and protective device control settings

- The HVAC control system wiring diagrams shall be functional wiring diagrams which show the interconnection of conductors and cables to HVAC control panel terminal blocks and to the identified terminals of devices, starters and package equipment. The wiring diagrams shall show necessary jumpers and ground connections. The wiring diagrams shall show the labels of all conductors. Sources of power required for HVAC control systems and for packaged equipment control systems shall be identified back to the panel board circuit breaker number, HVAC system control panel, magnetic starter, or packaged equipment control circuit. Wiring diagrams shall be submitted for each HVAC control system.

Service Organizations: A list of service organizations qualified to service the HVAC control system shall be provided. The list shall include the service organization name, address, technical point of contact and telephone number, and contractual point of contact and telephone number.

Equipment Compliance Booklet: The HVAC Control System Equipment Compliance Booklet (ECB) shall be provided. It shall consist of, but not be limited to, data sheets and catalog cuts which document compliance of all devices and components with the specifications. The ECB shall include a Bill of Materials for each HVAC control system. The Bill of Materials shall function as the table of contents for the ECB and shall include the device's unique identifier, device function, manufacturer, and model/part/catalog number used for ordering.

Performance Verification Test Procedures: The performance verification test procedures shall refer to the devices by their unique identifiers, and shall explain, step-by-step, the actions and expected results that will demonstrate that the HVAC control and LFH exhaust systems performs in accordance with the sequences of operation, and other contract documents.

Training: An outline for the HVAC control system training course with a proposed time schedule. Approval of the planned training schedule shall be obtained from the Government at least 60 days prior to the start of the training. Three copies of HVAC control system training course material 30 days prior to the scheduled start of the training course. The training course material shall include the operation manual, maintenance and repair manual, and paper copies of overheads used in the course.

Operation Manual, Maintenance and Repair Manual: The HVAC Control System Operation Manual and the HVAC Control System Maintenance and Repair Manual shall be provided for each HVAC control system.

15.4.2 HUMIDITY CONTROL

Summer and winter space or zone humidity control shall be provided only on a space-by-space or zone-by-zone basis and not for the entire central ventilation system unless required for project-specific humidity requirements as stated in the project criteria. No controls shall be provided for dehumidifying spaces to below 50 percent relative space humidity or for humidifying spaces to greater than 30 percent relative space humidity unless required by project-specific criteria.

15.4.3 SIMULTANEOUS HEATING AND COOLING

Simultaneous heating and cooling, which controls comfort conditions within a space by reheating or recooling supply air or by concurrently operating independent heating and cooling systems to serve a common zone, shall not be used except under the following conditions:

- Renewable energy sources are used to control temperature or humidity.
- Project-specific temperature, humidity, or ventilation conditions require simultaneous heating and cooling to prevent space relative humidity from rising above special-space relative humidity requirements.
- Project-specific building construction constraints, as established in the project criteria, prohibit installation of other types of HVAC systems.

15.4.4 MECHANICAL VENTILATION CONTROL

All supply, return, and exhaust ventilation systems shall be equipped with automatic and manual control of fan operation to shut off the fan when ventilation is not required. To prevent introduction of outside air when ventilation is not required, these systems shall also be provided with manual gravity-operated or automatic control of dampers for outside air intake and exhaust or relief. Systems that circulate air shall be provided with minimum outdoor air damper position control to ensure that the minimum amount of outdoor air is being introduced into the system. Unless otherwise required by life safety or the specific project criteria, automatic dampers should fail open for return air and fail to a minimum setting for outside air.

15.4.5 ENERGY CONSERVATION CONTROL SCHEMES

HVAC systems will be provided with automatic controls which will allow systems to be operated to conserve energy. The following energy saving controls will be considered, if applicable to the system:

- Enthalpy controlled economizer cycle
- Controls to close outside air supply when the facility is unoccupied (for non-laboratory areas only)
- Night setback controls where appropriate
- Master outdoor temperature sensing unit that resets the supply hot water temperature in accordance with outdoor ambient temperature. This sensing unit shall automatically shut off the heating system and the circulating pumps when the outdoor temperature reaches 65 degrees F (unless needed for research)
- Controls to shut off exhaust fans, where appropriate
- Reset controls for hot and cold decks on air conditioning systems having hot and cold decks.

15.4.6 AUTOMATIC CONTROL DAMPERS

Automatic air control dampers must be of the low-leakage type with a maximum leakage of 6 cfm per square foot at a maximum system velocity of 1,500 feet per minute (fpm) and a 1-inch pressure differential, as stipulated in Air Movement and Control Association (AMCA) standard 500. The dampers shall be opposed-blade type for modulating control, but may be parallel-blade type for two-position control. Pilot positioners and operators shall be out of the airstream.

15.4.7 VARIABLE-AIR-VOLUME SYSTEM FAN CONTROL

Variable-air-volume (VAV) systems shall be designed with control devices that sense ductwork static air pressure and velocity air pressure, and control supply-fan airflow and static pressure output through modulation of variable inlet vanes, inlet/discharge dampers, scroll dampers, bypass dampers, variable pitch blades, or variable frequency electric drive controls, as described in ASHRAE *HVAC Applications Handbook*, Chapter 41, and ASHRAE *Handbook of HVAC Systems and Equipment*, Chapter 18. These control systems shall have a minimum of one static pressure sensor mounted in ductwork downstream of the fan and one static pressure controller to vary fan output through either the inlet vane, the damper, the belt modulator, or the speed control. Exhaust fans, supply fans, and return or relief fans shall have devices that control the operation of the fans to monitor air volumes and maintain fixed minimum outdoor air ventilation requirements.

15.4.8 FIRE AND SMOKE DETECTION AND PROTECTION CONTROLS

All air-handling systems shall be provided with the smoke and fire protection controls required by NFPA 72. All supply, return, relief, and exhaust air ventilation systems shall have interlock controls that interface with the fire and smoke detection system controls. In the event of fire, these interlock controls shall either turn off or selectively operate fans and dampers to prevent the spread of smoke and fire through the building. These controls shall comply with NFPA 90A.

Special exhaust systems shall be designed to include fire and smoke safety controls as required by NFPA 91. Kitchen exhaust ductwork systems shall be designed to include all fire and smoke safety controls as required by NFPA 96.

Engineered smoke pressurization and evacuation systems shall comply with the following:
- NFPA 72
- NFPA 90A
- NFPA 92A

- ASHRAE manual, *Design of Smoke Control Systems for Buildings*
- ASHRAE *Handbook of HVAC Systems and Equipment.*

Special hazard protection systems that initiate an alarm shall be in accordance with the provisions in Section 16, Electrical Requirements, of this Manual.

15.4.9 GAS-FIRED AIR-HANDLING UNIT CONTROL

Gas-fired air-handling units shall be equipped with operating limit, safety control, and combustion control systems. Gas burner and combustion controls shall comply with Factory Mutual (FM) loss prevention data sheets and be listed in the FM Approval Guide. Gas-fired air-handling units shall have controls that lock out the gas supply in the following conditions:

- Main or pilot flame failure
- Unsafe discharge temperature (high limit)
- High or low gas pressure
- No proof of airflow over heat exchanger
- Combustion air loss
- Loss of control system actuating energy.

15.4.10 COOLING TOWER AND WATER-COOLED CONDENSER SYSTEM CONTROLS

Controls for cooling towers shall conform to NFPA 214, Standard on Water-Cooling Towers. Design of cooling tower fans shall consider use of variable-speed drives (if feasible) or two-speed motors (if feasible) and on/off controls to reduce power consumption and maintain condenser water temperature. Bypass valve control shall be provided, if required, to mix cooling tower water with condenser water in order to maintain the temperature of entering condenser water at the low limit. To decrease compressor energy use, condenser water temperature shall be allowed to float, as long as the temperature remains above the lower limit required by the chiller. The design shall provide basin temperature-sensing devices and, if the cooling tower is operated under freezing conditions, shall provide additional heat and control system components to maintain cooling tower sump water temperatures above freezing.

When appropriate, additional controls and sensors may be added to the condenser water system to provide condenser water to laboratory equipment that may require it. In addition, provisions for supplying emergency condenser water to laboratory equipment may be required.

15.4.11 CENTRAL CONTROL AND MONITORING SYSTEMS

The entire control system shall be connected to the central control and monitoring system (CCMS) network. The VAV controllers shall be fully compatible with the CCMS allowing complete monitoring, control, and setpoint adjustment of all VAV terminal unit controllers from the CCMS host. One personal computer must be provided for monitoring, controlling and resetting of any control device in the complex. This computer shall also serve as the connection through a modem to a CCMS. A minimum of one laptop computer shall also be provided for use as a field interface device to monitor, control, and reset any applicable point for any control device. The supplier of the control system shall provide three (3) copies of the operating software (one copy on the central control computer and 2 sets on CDs) and three (3) sets of technical manuals for the control system to the EPA. This system must be expandable to include the future phases.

15.4.12 ENERGY METERING

All utilities including electric, gas, oil, and potable water utilities to be monitored shall be metered and tracked by the central control and monitoring system (CCMS). All meters shall be compatible with the installed control system, shall be provided with signaling devices and shall fully interface with building HVAC control panel. Submetering of utilities to various buildings or equipment shall be based on project criteria or, in the absence of these, on sound engineering judgment. Sub-metering of lighting systems should also be considered.

15.4.13 DDC HARDWARE REQUIREMENTS

Units of the same type of equipment shall be products of a single manufacturer. Each major component of equipment shall have the manufacturer's name and address, and the model and serial number in a conspicuous place. Materials and equipment shall be standard products of a manufacturer regularly engaged in the manufacturing of such products, which are of a similar material, design and workmanship. The standard products shall have been in a satisfactory commercial or industrial use for two years prior to use on a project. The two years' use shall include applications of equipment and materials under similar circumstances and of similar size. The two years' experience shall be satisfactorily completed by a product which has been sold or is offered for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures. Products having less than a two-year field service record will be acceptable if a certified record of satisfactory, field operation, for not less than 6,000 hours exclusive of the manufacturer's factory tests, can be shown. The equipment items shall be supported by a service organization. Items of the same type and purpose shall be identical, including equipment, assemblies, parts and components.

Portable Workstation/Tester: A portable workstation/tester shall be a Dell Inspiron 2600 or equivalent. It shall include carrying case, extra battery, charger and a compatible network adapter. The workstation/tester shall:

- Run DDC diagnostics.
- Load all DDC memory resident programs and information, including parameters and constraints.
- Display any point in engineering units for analog points or status for digital points.
- Control any analog output (AO) or digital output (DO).
- Provide an operator interface, contingent on password level, allowing the operator to use full English language words and acronyms, or an object oriented graphical user interface.
- Display database parameters.
- Modify database parameters.
- Accept DDC software and information for subsequent loading into a specific DDC. Provide all necessary software and hardware required to support this function, including an EIA ANSI/EIA/TIA 232-F port.
- Disable/enable each DDC.
- Perform all workstation functions as specified.

Central Workstation/Tester: A central workstation/tester shall be tester shall be a Dell Dimension 4500 or equivalent. The central workstation/tester shall:

- Run DDC diagnostics.
- Load all DDC memory resident programs and information, including parameters and constraints.
- Display any point in engineering units for analog points or status for digital points.
- Control any AO or DO.
- Provide an operator interface, contingent on password level, allowing the operator to use full English language words and acronyms, or an object oriented graphical user interface.
- Display database parameters.
- Modify database parameters.
- Accept DDC software and information for subsequent loading into a specific DDC. Provide all necessary software and hardware required to support this function, including an EIA ANSI/EIA/TIA 232-F port.
- Disable/enable each DDC.
- Perform all workstation functions as specified.

15.4.14 DDC SOFTWARE REQUIREMENTS

All DDC software described in this specification shall be furnished as part of the complete DDC system. Updates to the software shall be provided for system, operating and application software, and operation in the system shall be verified. Updates shall be incorporated into operations and maintenance manuals, and software documentation. There shall be at least one scheduled update near the end of the first years' warranty period, at which time the latest released version of the Contractor's software shall be installed and validated.

15.5 Heating, Ventilation, and Air-Conditioning Systems

15.5.1 GENERAL

Selection of central station cooling systems shall be based on the LCCA procedures. Size, selection, and design shall be based on guidelines in the ASHRAE *Fundamentals, HVAC Systems and Equipment,* and *HVAC Applications* handbooks. Refrigeration equipment shall comply with Air-Conditioning and Refrigeration Institute (ARI) 520, ARI 550, and ARI 590. To ensure the most economical operation, the number and size of central station cooling units shall be based on the annual estimated partial-load operation of the plant.

- The project design criteria shall provide direction on installed standby chiller capacity. Wherever possible, the central station chilled-water equipment shall be designed into the chilled-water distribution systems as part of a primary-secondary loop system maintaining the chilled-water inlet temperature below a maximum predetermined value; ideally, the central station cooling equipment will be the secondary portion of the loop.

- Temperature-critical areas (such as laboratories and computer centers), as determined by project criteria, shall be provided with independent refrigeration systems with backup systems if the areas are involved with vital programs. Use of off-peak cooling systems shall be considered in areas that have high electric peak demand charges.

15.5.2 AIR-CONDITIONING SYSTEMS

The air-conditioning and refrigeration equipment for the mechanical systems shall use refrigerants acceptable under EPA's Significant New Alternatives Program (SNAP) under 40 CFR Part 82, Protection of Stratospheric Ozone. Chlorofluorocarbon (CFC) refrigerants shall be avoided. The use of hydrochlorofluorocarbon (HCFC) will be permitted only if the equipment required cannot be replaced with equipment that uses a non-ozone-depleting refrigerant. Existing chillers should be retrofitted or replaced to meet the requirements of 40 CFR Part 82. The refrigerant in air-conditioning systems should be recycled during servicing, as required under Section 608 of the Clean Air Act. Except as set forth herein, all air-conditioning and ventilating systems for the handling of air that is not contaminated with flammables or explosive vapors or dust shall conform to the requirements of NFPA 90A and 90B.

15.5.3 WATER CHILLERS

The selection of centrifugal, reciprocating, helical, rotary-screw, absorption, or steam-powered chillers shall be based on coefficients of performance under full-load and partial-load conditions; these coefficients are used in analysis done by LCCA methods. LCCA shall also consider the pumping-energy burdens on the chilled-water and condenser water system as part of the evaluation. Compression refrigeration machines shall be designed with the safety controls, relief valves, and rupture disks noted below, and design shall be in compliance with the procedures prescribed by ASHRAE 15 and Underwriters Laboratories (UL) 207.

- Controls shall include, at a minimum:
  - High-discharge refrigerant pressure cutout switch
  - Low-evaporator refrigerant pressure or temperature cutout switch
  - High and low oil pressure switches
  - Chilled-water flow interlock switch
  - Condenser water flow interlock switch (on water-cooled equipment)

- Chilled-water low-temperature cutout switch.

- Centrifugal compressors shall be designed to operate with inlet control or variable-speed control for capacity modulation. Units shall be capable of modulating to 10 percent of design capacity without surge. Reciprocating compressors shall be designed for capacity control by cylinder unloading. Designs using hot-gas bypass control of compressors for capacity modulation shall not be used except when capacity modulation is required at conditions below 10 percent of the rated load. Compressor motors for refrigeration equipment shall be selected in compliance with all requirements of the National Electrical Code (NEC).

- Absorption refrigeration machines shall be provided with the following safety controls, at a minimum:

  - Condenser water flow switch
  - Chilled-water flow switch
  - Evaporation refrigerant level switch
  - Generator high-temperature limit switch (gas-fired units)
  - Generator shell bursting disc (high-temperature water or steam)
  - Concentration limit controls.

- Liquid coolers (evaporators) shall be designed to meet the design pressure, material, welding, testing, and relief requirements of ASHRAE standard 15 and the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII. Evaporators shall be selected according to the requirements of ASHRAE standard 24-78.

15.5.4 CONDENSERS/CONDENSING UNITS

Water-cooled condensers shall comply with ASHRAE standard 15 and ASME Boiler and Pressure Vessel Code, Section VIII. Water-cooled condenser shells and tubes shall have removable heads, if available, to allow tube cleaning. The use of marine water boxes on the condenser shall be considered for ease of tube cleaning.

Air-cooled condensers and condensing units shall meet the standard rating and testing requirements of ARI 460 and ASHRAE standard 20. Air-cooled condenser intakes shall be located away from any obstructions that will restrict airflow. Air-cooled equipment shall be located away from noise-sensitive areas, and air-cooled condensers shall have refrigerant low-head-pressure control to maintain satisfactory operation during light loading.

15.5.5 COOLING TOWERS

Cooling towers shall be located and placed to avoid problems with water drift and deposition of water treatment chemicals. Cooling towers shall have ample clearance from any obstructions that would restrict airflow, cause recirculation of discharge air, or inhibit maintenance. Cooling tower location should consider noise for building and neighboring occupants.

15.5.5.1 Cooling tower acceptance and factory rating tests shall be conducted in accordance with Cooling Tower Institute (CTI) Bulletin ATC-105.

15.5.5.2 Cooling towers shall have a conductivity meter installed to monitor water chemistry and automatically control cooling tower blowdown and water treatment chemical addition. The conductivity meter shall be regularly calibrated and maintained. Cooling tower water treatment vendors shall be instructed that water conservation is a key operating consideration. Vendors shall be selected based on past performance, cost to treat 1,000 gallons of make-up water, and highest recommended water cycle of concentration.

15.5.5.3 Cooling towers shall have sump water heating systems if they will operate during freezing weather.

15.5.5.4 Combustible casings are acceptable in cooling towers, provided that the fill and drift eliminators are noncombustible. (Polyvinyl chloride (PVC) and fire-retardant-treated, fiberglass-reinforced plastic are classified as combustible.) In determining cooling tower requirements, the definitions of combustible and noncombustible in NFPA 214 shall be used. Cooling towers with more than 2,000 cubic feet of a combustible fill shall be provided with an automatic sprinkler system, designed in accordance with NFPA 214, when any of the following conditions exist:

- The continued operation of the cooling tower is essential to the operations in the area it services.
- The building is totally sprinkler protected.
- A fire in the cooling tower could cause structural damage or other severe fire exposure to the building.
- The value of the cooling tower is five or more times the cost of installing the sprinkler protection. The cost of the sprinkler protection shall include all factors involved, such as the sprinkler piping distribution system, the heat-sensing system, the control valve, and any special water supplies or extension of water supplies required.

15.5.5.5 Cooling towers with airstreams that pass through water shall have the water treated with an EPA-approved biocide to control etiological organisms or any chlorinated hydrocarbon pesticides, herbicides, or other chemicals that may be present because of local conditions. A maintenance program must be established to ensure continued, effective operation of these treatment systems.

15.5.5.6 Cooling towers shall have meters that measure water input (cooling tower make-up water) and output (blowdown water).

15.5.6 BUILDING HEATING SYSTEMS

This subsection applies to heat-generating equipment or heat-transfer equipment and accessories located in individual buildings. The project criteria shall provide direction on factors to be considered in the selection of heating system capacity; such factors include redundancy, future expansion or building modification, thermal storage or solar assistance, and other project-specific considerations. If maintaining the building design temperature is critical, a stand-alone heating system shall be designed with backup capability and with no dependence on other facility systems.

15.5.6.1 Where buildings are connected to the central plant heat generation/distribution system, one of the following shall be provided:

- Steam-to-building hot water heat exchanger
- High-temperature water (HTW)-to-building hot water heat exchanger
- Steam-pressure reducing station.

15.5.6.2 For space heating by hot water, conversion of the central heating plant steam or HTW shall provide a maximum heating-water supply temperature of 200 °F for building terminal units. For space heating by steam, the building steam supply pressure shall be reduced to 15 pounds per square inch gauge (psig) unless a higher supply pressure is needed for process requirements. For process-related or other high temperature requirements, the project criteria shall indicate the capacities and the temperature and pressure requirements. For facilities with a central plant condensate return system, a condensate receiver with duplex pumps shall be specified. Steam-to-hot-water or HTW-to-building heating water converters shall be selected on the basis of design criteria contained in the ASHRAE *Handbook of HVAC Systems and Equipment* and ASHRAE *HVAC Applications Handbook.*

15.5.6.3 The use of direct and indirect gas-fired units, electric heating, heat pumps (air-cooled and water-cooled), low-temperature gas infrared heating, and hot-water radiant heating and hot-water distribution to terminal units, shall be considered, with selection based on the building type, the facility preference, and LCCA. Office buildings, and particularly buildings with occupants sitting near fenestration, shall be designed with perimeter finned-tube radiation heating systems or other perimeter heating systems.

If the selected heating fuel is fuel oil, storage tanks, installed in accordance with national, state, and local regulations, shall provide 30 days of full heating capacity. Each tank shall be fully trimmed for safety and operating conditions and shall include a remote level gauge and full monitoring. Tanks shall comply with NFPA 30 requirements.

15.5.7 HEATING EQUIPMENT

Furnaces and boilers for central heating systems shall be enclosed in a room with 2-hour fire-rated walls, floors, and ceilings, and with openings protected by automatic or self-closing 1 ½-hour fire doors. For small units consisting of a single furnace operating a hot air system or a boiler not exceeding 15 psi pressure or a rating of 10 bhp, a 1-hour fire-rated enclosure is permissible.

15.5.7.1 STANDARDS

Heating equipment will comply with the following standards, except where noted otherwise:

- Oil-fired – NFPA 31
- Gas-fired – NFPA 54
- Liquefied petroleum gas-fired – NFPA 58
- Liquefied natural gas-fired – NFPA 59A
- Boiler and Combustion Systems Hazard Code – NFPA 85.

15.5.7.2 FUEL STORAGE

Where liquid fuel is used, a recessed floor or curb shall be provided, with ramps at the openings. The height of the recess or curb shall be sufficient to contain all the fuel in case the tank or container ruptures. For requirements, refer to NFPA 30, NFPA 45, NFPA 90A, and Chapter 5 of the Environmental Management Guidelines (Volume 4).

15.5.7.3 SHOP OPERATIONS

Shop, storage, and other operations that involve flammable or combustible materials and are not directly related to the operations in the furnace or boiler rooms shall be located elsewhere unless the furnace or boiler room is sprinkler protected. Incidental operations that do not utilize significant amounts of flammable materials are allowed in furnace or boiler rooms if proper separations are maintained between combustible materials and ignition sources (e.g., boiler equipment).

15.5.7.4 BURNERS

Regardless of size, burners on suspended oil-fired heaters shall be provided with flame supervision that will ensure shutdown in not more than 4 seconds if flame failure occurs or trial for ignition does not establish a flame.

15.5.7.5 GAS PIPING

Gas piping entry into the building shall be protected against breakage due to settling, vibration, or, where appropriate, seismic activity. Where practical, piping shall be brought in above grade and provided with a swing joint before it enters the building. Where it is necessary for gas piping to enter a building below ground, the physical arrangement shall be such that a break in the gas line due to settling or other causes at or near the point of entry cannot result in the free flow of gas into the building. Gas piping shall not be run in any space between a structural member and its fireproofing.

Pipelines shall be labeled in accordance with OSHA's hazard communication standard. Local gas utility and code requirements shall be followed.

15.5.7.6 GAS METER REGULATORS

To avoid placing any strain on the gas piping, any meters, regulators, or similar attachments shall be adequately supported. Any vents or rupture discs on the equipment shall be vented to the outside of the building.

15.5.7.7 VALVES

Earthquake-sensitive shutoff valves shall be provided for each gas entry, where required by local code.

15.5.7.8 GAS METER ROOMS

Gas meter rooms shall be vented in a way that removes any leaked gas without transporting it through the structure.

15.5.7.9 FIRE-RESISTANT SHAFTS OR CONDUIT

For large-capacity gas services (piping greater than 3-inch diameter at 4 inches of water pressure head or any other size with equivalent or greater delivery capabilities) within a building, the piping shall be enclosed in fire-resistive shafts and vented directly to the outside at top and bottom. Any horizontal runs of the gas pipe shall be enclosed in a conduit or chase, also directly vented at each end to the exterior or to the vented vertical shaft. Automatic gas detection and automatic shutoff shall be provided.

15.5.8 TWO-PIPE COMBINATION HEATING AND COOLING SYSTEMS

Under normal circumstances, two-pipe combination heating and cooling systems shall not be considered.

15.5.9 WATER DISTRIBUTION SYSTEMS

Economical pipe sizes shall be selected for chilled water, hot water, condenser water, boiler feed, and condensate return systems based on the allowable pressure drop, flow rate, and pump selection criteria prescribed in the ASHRAE *Fundamentals*, *HVAC Systems and Equipment*, and *HVAC Applications* handbooks. Insulation shall be provided on all water distribution piping and system components. Strainers shall be provided at the suction side of each pump and of each control valve. Flexible connectors shall be specified for installation on the suction and discharge piping of base-mounted end-suction type pumps and on electronically driven chillers.

- Check valves and balancing valves, or combination check-shutoff-balance valves, shall be installed in the discharge piping of all pumps operating in parallel pumping systems. Balancing valves shall be installed in the discharge piping of all pump systems.

- Service valves shall be installed in the suction and discharge piping of all major pieces of equipment. Balancing valves shall be provided in the discharge piping of all coils and in central station cooling equipment.

- An air elimination pressure control, venting, and automatic filling system (with backflow prevention) shall be provided for each hot-water and chilled-water distribution system; water treatment injection should also be provided, if required.

- Air chambers and/or surge tanks should be installed to safeguard system against water hammer.

- Expansion or compression tanks and fill piping connections shall be located on the suction side of the distribution system pump or pumps. Expansion tanks and air separation devices shall be sized according to the methods in the ASHRAE *Handbook of HVAC and Equipment*, and specified in accordance with the requirements of ASME B31.1. Gauge glasses, drain valves, and vent valves shall be provided for all expansion tank systems.

- Water treatment design information for chilled water, hot water, and boiler feed water systems shall be based on project criteria (tested water condition).

15.5.10 PUMPS AND PUMPING SYSTEMS

Pumps for chilled-water, hot-water, condenser water, boiler feed water, and condensate systems shall be centrifugal-type pumps and shall be selected on the basis of the criteria in the ASHRAE handbooks. Materials, types of seals, bearings, wear rings, shafts, and other features shall be selected on the basis of specific system requirements. Use of primary-secondary type pumping systems and high-efficiency motors shall be considered for pumps for all hot-water and chilled-water distribution systems.

- For systems where system pumping horsepower requirements are greater than 20 bhp, use of variable-speed drives or parallel-pumping arrangement shall be considered.

- Standby pumps shall be provided for all systems, unless dictated by project-specific criteria.

15.5.11 STEAM DISTRIBUTION SYSTEMS

All steam piping shall comply with ASME B31.1 and shall be at least Schedule 40 black steel. Fittings, valves, and accessories shall be selected on the basis of pipe size and temperature and pressure conditions.

15.5.11.1 STEAM CONDENSATE RECOVERY

Steam systems shall incorporate condensate recovery. The condensate recovery system shall be routinely inspected and maintained to maximize the recovery of condensate.

15.5.12 AIR-HANDLING AND AIR DISTRIBUTION SYSTEMS

Air-handling equipment and air distribution systems shall be sized to optimize performance, initial cost, and operating and maintenance costs over the life of the system. Systems should be sized for 25% future expansion in fume hoods, other ventilated equipment, and to accommodate future modernization requirements.

15.5.12.1 SETBACK MECHANISM

The setback mechanism shall provide a low-speed operations setting for the fan motors of air-handling unit(s) and fume hoods in a particular zone. Fan motors can be simultaneously activated. The setback mechanism shall be designed to provide four air changes per hour or 25 cfm per square foot of LFH work surface. The setback mechanism shall also provide room temperatures of approximately 55 °F in the winter and approximately 85 °F in the summer unless other, overriding temperature requirements are specifically stated. The exhaust requirements of LFHs and other exhaust devices, as well as the temperature and humidity requirements, shall override laboratory minimum air changes per hour.

The HVAC system(s) nighttime setback shall be controlled by a timer connected to the energy management control system of the building. The fume hood face velocity reduction of 25 percent of full open-flow air volume (80 fpm hood face velocity at 100% sash opening) and the general exhaust and special canopy hood operation at 100 percent airflow are to be balanced by an appropriate reduction in supply air (air-handling unit) fan speed in order to maintain negative pressure in the laboratory and laboratory support rooms with respect to the hallways.

15.5.12.2 NOISE LEVELS

All air-handling system equipment (e.g., fans, terminal units, air-handling units) shall be provided with vibration isolators and flexible ductwork connectors to minimize transmission of vibration and noise. Systems shall satisfy the noise criteria (NC) levels recommended for various types of spaces and the vibration criteria listed in the ASHRAE handbooks. The combined noise level generated by mechanical and electrical building equipment and fume hoods should not exceed 70 decibels dBa at the face of the hoods (with the systems operating) or 55 dBa elsewhere. Where air-handling equipment and air distribution systems cannot meet these requirements, sound, and vibration-attenuation devices shall be installed in the air-handling systems.

15.5.12.3 VAV MECHANICAL VENTILATION

Use of a VAV mechanical ventilation system is permitted if the following design and installation criteria are achieved.

- VAV system must maintain a minimal flow of air within the laboratory fume hood and ductwork to purge gases, vapors, and other substances; avoid condensation, impaction, and deposition in the ductwork; and achieve sufficient exhaust stack velocity so that the contaminated air stream clears the building and does not reenter the building along with supply air. Refer to subsection 15.3.2 for minimum airflow requirements.

- The system must be able to consistently provide 100 fpm average face velocity for restricted bypass laboratory fume hoods at 80% face opening and all face openings below 100% until the minimum exhaust volume of 25 CFM per square foot of LFH work surface is reached.

- The supply and exhaust motors in the VAV system must be able to respond with no unacceptable delays to changes in the sash height. This will prevent the backflow of contaminants into the workspace and the temporary loss of negative pressure in the laboratory space relative to corridors and other adjacent spaces.

15.5.12.4 AIR HANDLER CONDENSATE

Reuse of air handler condensate shall be considered, particularly in geographic locations with extended periods of warm, humid climate conditions. In applications where air handler condensate reuse is cost effective, it should be implemented. Condensate should ideally be used as cooling tower make-up, or for other appropriate applications.

15.5.13 FANS/MOTORS

Fans shall be designed and specified to ensure stable, nonpulsing aerodynamic operation in the range of operation, over varying speeds. Fans with motors of 20 horsepower (hp) or less shall be designed with adjustable motor pulley sheaves to assist in air balancing of systems. Fans with motors of greater than 20 hp shall use fixed (nonadjustable) drives that can be adjusted by using fixed motor pulley sheaves of different diameters. Supply air-handling units and return air fans in VAV systems shall control capacity through the use of variable-speed drives, inlet vanes, or scroll bypass dampers. All fans shall comply with AMCA standard 210, ASHRAE standard 51, the ASHRAE *Handbook of HVAC Systems and Equipment*, and ACGIH *Industrial Ventilation*.

- Fans shall be located within the ductwork system, in accordance with the requirements of AMCA Publication 201. Motors shall be sized according to properly calculated bhp fan requirements and shall not use oversized fans and motors to meet future capacity needs unless so directed by the project criteria. Fan construction materials shall be selected on the basis of corrosion resistance and cost. Spark-resistant construction shall be used where required by NFPA. All fans and accessories shall be designed and specified to meet all smoke and flame spread requirements of NFPA 255. Fans used in exhaust systems of fume hoods shall also be of the noiseless type and shall be corrosion-resistant to the fumes generated in the hood.

- Smoke detectors for automatic control in air distribution systems shall be located in accordance with the requirements of NFPA 90A, Chapter 4.

15.5.14 COILS

Heating and cooling coils shall comply with ARI 410. Heating and cooling coil selection shall comply with the guidelines in the ASHRAE *Handbook of Fundamentals* and the ASHRAE *Handbook of HVAC Systems and Equipment*. Coil manufacturers shall certify coil performance by ARI certification or provide written certification from a nationally recognized independent testing firm that coil performance is in accordance with ARI 410.

- Heating and cooling coils shall be composed of materials appropriate for the corrosive atmosphere in which they operate. Cooling coils shall be designed with a maximum face velocity of 550 fpm. Coils designed with face velocities exceeding 500 fpm shall have features that prevent condensate carryover or use moisture eliminators. Coils shall have a drain feature.

- Recirculating air systems designed for outside-air winter temperatures below freezing shall have a preheat coil located either in the outside air intake or in the mixed-air stream upstream of the cooling coil, unless the theoretical mixed-air temperature is calculated to be above 35°F. In this case, the preheat coils may be omitted if adequate baffling is provided to guarantee positive mixing of the return and outdoor air. Preheat coils shall be designed to maintain discharge air temperature without modulation of the steam or hot-water flow through use of modulating face dampers and bypass dampers. In moderate climates where the method has been proved to be reliable and there is no concern about coil freeze-up, steam modulation may be used for control of steam coils.

15.5.15 WALK-IN ENVIRONMENTAL AND COLD STORAGE ROOMS

Walk-in environmental rooms are rooms in which temperature and/or humidity is controlled at a single set condition within specified tolerances regardless of activity in the room. In determining the appropriate room temperature, uniformity, and gradient, the design professional should discuss heat loads (in terms of process loads and ventilation requirements) with the end user. Walk-in environmental rooms shall be capable of maintaining a 4°C room temperature with a uniformity of ±0.5°C and a maximum gradient of 1°C, unless otherwise specified in the program requirements. A walk-in cold storage room shall be capable of maintaining a minus 20°C room temperature with a uniformity of ±1°C and a maximum gradient of 3°C, unless otherwise specified. Rooms shall feature temperature displays visible from a contiguous hallway and shall be capable of producing a continuous record of temperature. Alarm systems with manual override capability shall be provided to advise room operators of fault conditions. Ventilation shall be provided if work activity is performed inside chambers/rooms. Doors to rooms shall be provided with a locking mechanism capable of release at all times from the room interior whether or not the door is locked. Walk-in environmental and cold storage spaces shall include shelving. Walk-in coolers are considered enclosed spaces and require automatic fire sprinkler protection inside them. Walk-in cold storage rooms shall have O^2 sensors and alarms to ensure that oxygen has not been displaced.

A separate refrigeration system shall be provided for these rooms. If refrigeration is provided by the main building's chilled-water system, a backup self-contained system shall also be provided.

15.5.16 CENTRAL PLANT HEAT GENERATION AND DISTRIBUTION

The following criteria shall be applied in the planning and design of steam and HTW generation and distribution systems and of cogeneration facilities.

15.5.16.1 FACILITY SIZING

The design professional shall consider creating a plant design that can be easily expanded to meet potential future loads in addition to meeting confirmed near-term loads. Load computations to establish boiler capacity shall be based on the building design heating load, as determined in conformance with the ASHRAE *Handbook of Fundamentals*, plus process heating loads (if any) and an allowance for piping plants. The process heat losses shall be investigated during the design stage to determine whether heat can be recovered, thereby reducing the boiler load.

Multiple boiler installations shall be considered for all applications in order to maintain high operating plant efficiency throughout the year. The number and size of the boilers shall be based on the number of operable hours at full and partial load operation, the turn-down ratio of the boiler being considered, efficiency at partial loads, and year-round process or summer loads. Use of a base load boiler shall be considered when a year-round process demand exists. The system shall be designed to satisfy peak demand by operating over its maximum rating for short periods of time.
The possibility of operating small local boilers rather than the central plant to satisfy summer loads shall also be considered. Sufficient capacity shall be furnished to allow one boiler to be down for inspection or maintenance or to be on standby while the remaining boiler(s) maintain normal operations.

The generating facilities shall be so located as to allow efficient steam/hot-water distribution throughout the site and to allow for future expansion of the generating and distribution system. The facility location shall also be chosen to take advantage of prevailing winds and to minimize problems associated with noise, dirt, air pollution, harmful effects on adjacent property owners, and accommodation of fuel deliveries and storage.

The option of installing one or more satellite boiler facilities rather than a single central boiler complex shall be evaluated when one or more of the following conditions exist:

- An extensive distribution system connecting several separate steam users is required.
- Requirements exist for several different steam pressures.
- Variable steam loadings exist with respect to time or quantity.

The use of a cogeneration plant as a possible alternative shall be considered in the planning of any large steam generation facility. The feasibility of cogeneration with HTW or HTW boilers or HTW-to-steam generators shall be considered. In determining the feasibility of cogeneration, the following factors shall be considered:

- Energy demand and cost, peak load, average load, seasonal variations, and utility rate structures.
- Regulatory concerns: Public Utility Regulatory Policies Act (PURPA), relevant environmental regulations, and current local regulations.

The applicability of cogeneration shall be thoroughly evaluated per EPA Cogeneration Partnership Program (www.epa.gov/chp/about_chp.htm). Cogeneration plants shall be sized to accommodate existing loads.

15.5.16.2 STEAM AND HIGH-TEMPERATURE WATER GENERATION

All boilers shall comply with the ASME Boiler and Pressure Vessel Code. In determining whether to select a steam or a high-temperature water (HTW) system, the following factors shall be considered:

- Whether the system will be operated intermittently or continuously
- Whether fast response to significant load variation is important
- Pumping costs
- Length, size, and configuration of required piping
- Possibility of using HTW to generate the steam at its point of use, in a facility where only a few processes require steam.

Steam boilers shall be designed to provide dry, saturated steam unless the economics of electricity generation, meeting specific process requirements, or accommodating extensive distribution systems necessitates use of superheated steam. If required for process, the use of high-pressure satellite boilers located close to the process shall be considered in lieu of distribution of high-pressure steam.

An HTW system is a system that generates heating or process water with a temperature above 300°F. HTW boilers shall be of the controlled forced-circulation type, specifically designed for HTW service. Because of costs associated with high-pressure pipe, valves, and fittings, HTW systems should not be designed for higher temperatures and pressures than are absolutely necessary.

In a gas-pressurized HTW system, an inert gas, such as nitrogen, shall be used and the pressurizing tank shall be installed vertically to reduce the area of contact between gas and water, thus reducing the absorption of gas into the liquid. Gas-pressurized systems should be maintained at a pressure that is well above the pressure at which the HTW will flash to steam. Pump pressurization is generally restricted to small process heating systems. In larger HTW systems, pump pressurization can be combined with gas pressurization.

Boilers shall be equipped with meters to measure total potable water used as boiler feed water.

15.5.16.3 CIRCULATION PUMPS

In selecting and installing circulation pumps, energy efficiency shall be emphasized. Consideration shall be given to the use of variable-speed circulation pumps. In steam-pressurized systems, circulating pumps shall be located in the supply lines to maintain pressure above the flashpoint of the hottest water in the distribution system. A mixing connection that allows some of the coil return water to pass into the supply line at the pump suction shall be provided to safeguard against flashing or cavitation at the pump(s). In a gas-pressurized HTW system, the circulating pumps may be installed in either the supply lines or the return lines.

15.5.16.4 FUEL STORAGE AND HANDLING SYSTEMS

Control, containment, and treatment of rainwater runoff from coal storage yards shall comply with effluent guidelines and standards for steam-electric power-generating point sources (40 CFR Part 423). The relative economy of a central natural gas–fired plant compared with a gas distribution system serving the individual requirements of each building shall be considered. The long-range availability of the gas supply and the possible need for a secondary fuel shall be established. The economics of interruptible versus uninterruptible gas service relative to availability of secondary fuel shall be considered.

Fully automatic mechanical-firing equipment and mechanical draft equipment shall be provided. Mechanical-firing equipment capable of developing 100 to 125 percent of the boiler capacity shall be specified.

Ash-handling systems shall comply with Federal Construction Council Technical Report No. 51, Chapter III, Section 3.1. Land availability for storage or disposal, water availability, nearness to residential areas, the possibility of selling the ash, as a means of disposal, and environmental regulations shall be considered. Collection and treatment of ash-carrying liquid effluents shall comply with 40 CFR Part 423.

Stationary internal combustion engines, such as gasoline- or diesel-powered generators or fire pumps, shall conform to the requirements of NFPA 37.

The use of underground tanks shall be avoided. Refer to Chapter 5 of the *Environmental Management Guidelines (Volume 4)* for storage tank requirements (aboveground and underground).

15.5.16.5 BOILER WATER TREATMENT

Boiler water treatment shall be provided to prevent deposits on or corrosion of internal boiler surfaces and to prevent the carryover of boiler water solids into the steam. A boiler water treatment specialist shall be consulted to determine appropriate treatment measures. Water quality measures for the steam plant and for other site process water users should be coordinated. The design of the plant shall provide for daily sampling to determine internal water conditions. Provisions shall be made for introducing treatment chemicals into the feed water. The plant shall contain adequate space and equipment for storing, handling, and mixing chemicals. Continuous versus intermittent blowdown operations shall be considered to determine which system will keep the concentration of total solids within acceptable limits. For continuous blowdown operations, the economics of installing a heat recovery system shall be considered. Blowdown rates and boiler water chemistry control shall be established in consultation with ASME's "Consensus Operating Practices for Control of Feedwater/Boiler Water Chemistry in Modern Industrial Boilers " (1994).

A minimum of two boiler feed pumps, each sized to handle the peak load, shall be provided to allow one pump to be out of service without affecting facility operations. Pumps shall be equipped with automatic controls that regulate feed water flow to maintain the required water level and with a relief valve. Relief valves shall be preset to lift at a lower pressure than the boiler safety valve setting plus static and friction heads.

15.5.16.6 BOILER ROOM CONTROLS AND INSTRUMENTATION

Boiler plant instrumentation and control panels shall include devices for monitoring the combustion process and consoles in equipment in which such devices are mounted. Boiler room controls and instrumentation shall comply with NFPA 85.

15.5.16.7 PLANT INSULATION

All hot surfaces within 7 feet of the plant floor, or on any catwalk, shall be insulated to prevent surface temperatures above 60 °C (where contact would be unintentional and unlikely) and above 49 °C (where contact is likely or necessary for equipment operation). Insulation shall be in accordance with the manufacturer's recommendations and the ASHRAE *Handbook of Fundamentals*.

15.5.16.8 STEAM AND HIGH-TEMPERATURE WATER DISTRIBUTION

Steam and HTW distributions systems shall be sized to accommodate, without extensive modification, any future expansion anticipated in the project criteria.

- When aboveground steam or HTW distribution systems are to be constructed, pipe shall be installed on concrete pedestals, on concrete/steel stanchions, or on poles. Where piping crosses over roadways, a minimum of 14 feet of clearance shall be provided.

- Provisions shall be made for expansion and contraction in the piping system. Expansion loops shall be provided where space allows. Where space does not allow expansion loops, expansion joints may be used. Piping shall comply with ASME B31.1

- Unless economics dictates otherwise, steam shall be supplied to the distribution system at the lowest pressure that will adequately serve the connected load. The economics of higher pressure distribution shall be considered. Processes requiring higher pressures shall be serviced, where practical, by a separate section of the distribution system to avoid operating the entire system at higher pressures than necessary.

- Warm-up bypass valves shall be provided at all shutoff valves in steam distribution lines. Steam velocities shall be selected for the type of service being considered but shall not exceed 10,000 fpm.

- Steam and condensate pipe shall, where possible, be graded at a minimum of 1 inch in 40 feet in the direction of flow. Drip stations and steam traps shall be provided at all low points in steam lines.

- To ensure tightness of the steam system, all joints to valves and fittings that are larger than 1.25 inches shall be welded, except in the boiler house, where flanges shall be used to facilitate maintenance of equipment, connections, and valves.

- HTW piping shall be sized for an average velocity of 5 feet per second, a maximum velocity of 10 feet per second, and a minimum velocity of 2 feet per second. To ensure tightness of the HTW system, all joints to valves and fittings that are larger than 1.25 inches shall be welded, except in the boiler house, where flanges shall be used to facilitate maintenance of equipment, connections, and valves.

- Unlike steam piping, HTW piping may follow the natural terrain; however, proper provisions shall be made for draining and venting the piping.

15.5.16.9 PIPING INSULATION

Insulation containing asbestos is prohibited. The possibility that water infiltration will cause physical damage to, or loss of thermal characteristics of, underground pipe insulation shall be considered in the selection of insulation. All insulation installed aboveground, in tunnels, and in manholes shall be provided with either a metal jacket, either factory or field installed, or a hard cement finish.

15.5.16.10 PIPING MARKING

Pipes shall be marked in accordance with ASME AB.1-1996 *Scheme for Identification of Piping Systems*, and shall conform with requirements of Chap. 5 of the GSA Facilities Standards for the Public Buildings Service, 2003 Edition (PBS P100); and NFPA 45, Chap. 8.2, *Storage and Piping Systems for Compressed and Liquified Gases*, 2000 Edition, as applicable

15.6 Ductwork

15.6.1 GENERAL

Ductwork systems shall be designed for efficient distribution of air to and from the conditioned spaces; noise, available space, maintenance, air quality, air quantity, and optimum balance between expenditure of fan energy (annual operating cost) and duct size (initial investment) shall also be considered.

Duct smoke detectors, as described under Section 16 Electrical Requirements, of this Manual, shall be installed in accordance with NFPA 90A requirements.

15.6.2 FABRICATION

Ductwork for air supply, return air, and general exhaust shall be fabricated of galvanized sheet metal, or fiberglass-reinforced plastic (FRP) that meets required fire ratings. Laboratory fume hood (LFH) and equipment exhaust shall be of PVC-coated galvanized sheet metal or of Type 316 welded stainless steel, depending on the specific laboratory function and type of process being exhausted. Polypropylene and glass duct material shall be considered for highly corrosive exhaust applications. LFH exhaust ductwork shall be of welded or flanged/bolted air tight construction in accordance with ANSI/AIHA Z9.2 and Z9.5

Duct linings or coverings shall be of noncombustible construction. The total assembly of the duct lining, including adhesive and any coatings or additives involved, shall have an interior finish rating of Class A (flame spread 0-25, smoke developed 0-450). Use of porous duct liners that can collect dirt and moisture should be avoided and shall not be considered for new construction. Where such liners are already in use, and particularly in areas close to humidification or dehumidification (cooling) equipment, the lining should be removed unless coated or sealed to prevent fiber loss.

15.6.2.1 COMPLIANCE

Ductwork systems shall be designed to meet the leakage rate requirements of the SMACNA *HVAC Air Duct Leakage Test Manual*. Ductwork, accessories, and support systems shall be designed to comply with the following:

- ACGIH *Industrial Ventilation Manual*
- ASHRAE *Handbook of Fundamentals*
- NFPA 45 Fire Protection for Laboratories Using Chemicals
- NFPA 90A Installation of Air-Conditioning and Ventilating Systems
- NFPA 91 Installation of Exhaust Systems for Air Conveying of Materials
- NFPA 96 Ventilation Control and Fire Protection of Commercial Cooking Operations
- SMACNA HVAC Duct Construction Standards - Metal and Flexible
- SMACNA Fibrous Glass Duct Construction Standards
- SMACNA Round Industrial Duct Construction Standards
- SMACNA HVAC Duct Design Manual.
- ANSI/ASHRAE 62
- ANSI/ASHRAE Z9.2
- ANSI/ASHRAE Z9.5

15.6.2.2 SPECIAL APPLICATIONS

Ductwork shall also meet the following requirements:

- Ductwork shall be designed to comply with NFPA 90A. This includes specifications and installation of smoke and fire dampers at rated wall penetrations and smoke pressurization/containment dampers as required for smoke pressurization/evacuation systems. Fire dampers shall not be used on the exhaust system ducting if the system must maintain confinement of hazardous materials during and after a fire.

- Ductwork shall be designed to resist corrosive contaminants if any are present. Exhaust ductwork from laboratory fume hoods shall not be of spiral construction and shall be sloped toward the fume hood for drainage of condensation, constructed with welded longitudinal seams, and welded transverse joints, or equivalent construction, in accordance with the requirements of Section 6, Ductwork, of American National Standard (ANSI/AIHA) Z9.5-1992. Laboratory ductwork shall be in accordance with the requirements of NFPA 45.

- Ductwork that handles moisture-laden air that is exhausted from areas such as shower rooms, dishwashing areas, and other areas where condensation may occur on the duct interior shall be of aluminum construction, have welded joints and seams, and provide drainage at low points.

- Penetrations of ductwork through security barriers shall be minimized. Any such penetrations that are more than 96 square inches in area and 6 inches in smallest dimension must be provided with a penetration delay equal to that required for the security barrier. The physical attributes, intended service of the ductwork, and the axial configuration of the barrier penetration shall be considered in the design of the penetration delay.

15.6.3 ACCESS PANELS

All ductwork shall have an access panel that provides access to each operating part, including:

- Splitter dampers
- Manual volume dampers
- Motorized volume damper
- Fire dampers.

15.6.4 INSULATION

All supply air ductwork shall be insulated with a vapor barrier unless otherwise dictated by the project criteria. Supply air ductwork installed below ceilings and in conditioned spaces may not require insulation if the surrounding air has a low dew point and condensation will not occur. Return and exhaust air ductwork may be insulated where condensation may occur when air is routed through unconditioned areas.

15.6.5 FIRE DAMPERS

Fire dampers shall be provided in accordance with codes, except in the exhaust systems of laboratory areas.

15.7 Laboratory Fume Hoods

EPA laboratory fume hoods, as constructed, manufactured, installed, and used, shall conform to current EPA requirements. The design professional, in consultation with the users of the facility, shall be responsible for selecting fume hood types and sizes that are appropriate to the hoods' intended use. The requirements of this subsection and of Chapter 4 of the *Safety Manual* shall be followed. Laboratory fume hoods shall be considered an integral part of the overall building HVAC system and shall be part of the laboratory mechanical system testing and balancing prior to building acceptance.

15.7.1 LABORATORY CONTROL DESIGN CONSIDERATIONS

Major projects will require the services and review of a qualified engineer with experience of controls design for laboratory fume hood. The following consideration shall be implemented during new and existing design process:

- Identify any user-specific needs for fume hood lab environmental monitoring.
- Identify any specific containment requirements.
- Determine the type of fume hood needed to perform operation
- Identify if constant (full bypass) or VAV (partial bypass) fume hood controls are to be used.
- Confirm satisfactory ASHRAE 110 performance testing of potential fume-hood/control-system configurations.
- Analyze expected laboratory space air flow dynamics to evaluate whether air flow tracking, active pressurization control or a combination of both is required.
- Carefully select the location and type of supply air diffusers. Supply diffusers shall be Titus, Radia Tec, dome faced radial perforated diffusers or equal.
- Determine the failure mode of all terminal boxes to ensure that the lab pressurization criteria are met under all condition.
- Confirm that laboratory temperature control does not override the minimum fume hood driven ventilation requirements.
- Identify all temperature control zones within the lab, and provide sufficient sensors to control each zone.
- Confirm that potential control suppliers have adequate presence and technical depth at the project location to support the project installation, testing and operation

Additional consideration for existing facilities design process:

- Analyze total system - air flows, pressures and temperatures.
- Select fume hood control type and size.
- Alter or re-balance the HVAC system and reset controls to maintain proper air flows and temperatures.

15.7.2 HOOD REQUIREMENTS

EPA fume hoods shall have an ASHRAE performance rating, as manufactured, of 4.0 AM 0.05 and shall conform to current EPA requirements. Before EPA purchases any hood model, the laboratory fume hood manufacturer, at a test facility provided by the manufacturer, and at no cost to the Government, shall certify the proper performance of the fume hood in accordance with the *Procedures for Certifying Laboratory Fume Hoods to Meet EPA Standards*. After the new hoods are installed, EPA requires the manufacturer to evaluate and certify in a written report that the installation and performance of the hoods complies with EPA specifications prior to acceptance and use by EPA. This shall occur after the testing and balancing (TAB) report is approved by AEAMB and SHEMD.

SHEMD is responsible for approving the certification of fume hoods. SHEMD will document the approval of all newly installed fume hoods for AEAMB. A list of approved or certified hoods is available from SHEMD.

Materials used in the construction of fume hoods and of exhaust blowers shall meet corrosion-resistance standards for the chemicals used and generated in the hood, as described in the hood uses; blowers should be rated or otherwise approved for use; and plumbing fixtures and electrical outlets should meet existing codes. In addition, fume hoods shall meet the following requirements:

- Ceiling and wall supply s for the distribution of supply air in the laboratory shall be designed for a maximum air velocity of 25 fpm at 6 feet above the finished floor at the face of the hood. HVAC diffusers shall be located so that they do not “short circuit” the airflow to a hood. Supply diffusers shall be similar or equal to the Titus, Radia Tec, dome faced radial perforated diffuser.

- Face Velocities: In accordance with *Procedures for Certifying Laboratory Fume Hoods To Meet EPA Standards*, the fume hood must be designed for an average face velocity of 100 fpm ± 10 fpm with sash 80% open with a uniform face velocity profile of ± 20% for point measurements in a traverse of the face opening. SHEMD will consider requests to operate hoods at 80 fpm average face velocity with a sash opening of 80%. Any request for a lower operating average face velocity should include information on the performance of the hood at lower operating velocities, the location of the hood and the type and location of ceiling supply air diffusers. Under no circumstances can the control velocity be less than 80 fpm at any sash height.

- The sash shall be equipped with a control device to maintain it at the operating height (e.g., releasable sash stops).

- Fume hoods shall be equipped with a low exhaust flow safety alarm system designed to signal unsafe operating conditions whenever fume hood average face velocity falls below 70 fpm. The alarm system shall consist of an audible and visual alarm to indicate malfunction or unsafe operating conditions. Additional specific standard utility and service requirements shall be indicated for each specific laboratory facility project.

15.7.3 CONSTANT VOLUME BYPASS-TYPE FUME HOOD

The laboratory fume hood is often an integral part of the building exhaust system. The volume of air exhausted should be constant, achieved by an airflow bypass above the sash through which room air can pass as the sash is lowered. A horizontal bottom and a vertical side airfoil must be specified and used on all hoods, and the face edges must be shaped to minimize entering air turbulence. Vertical foils on the sides also result in a slight airflow improvement by minimizing the eddies caused as air enters the hood. The work surface should be recessed three-eighths of an inch or more so that spills can be effectively contained. The front raised edge should extend just past the airfoil but not far enough to be used as a working surface near the face opening.

The bypass sizing and design must be such that the following conditions are met:

- The total airflow volume is essentially the same at all sash positions. As the sash is lowered, the face velocity increases to a rate that shall not exceed three times the design velocity for a fully open sash position.

- The bypass must provide a barrier between the hood work space and the room when the sash is lowered.

- The bypass opening is dependent only on the operation of the sash. Selected sash configurations are listed and described below:

- The vertical-rising fume hood sash shall be full-view type providing a clear and unobstructed side-to-side view of the fume hood interior and the service fitting connections. The sash shall be 7/32-inch laminated safety glass. The sash system shall utilize a single-weight pulley cable counterbalance system permitting one-finger operation along the length of the sash pull. The counterbalance system will hold the sash at any position without creep and will prevent sash drop in the event of malfunction or failure of a cable.

- The combination vertical-rising and horizontal-sliding fume hood sash shall be similar in design to the vertical-rising sash configuration but with multiple horizontal sliding sashes of 7/32-inch laminated safety glass panels on multiple tracks within the vertical rising sash frame.

While current EPA policy discourages the use of auxiliary air-type hoods in new construction, their use may be justified under special circumstances, such as in renovations where the existing ventilation system is inadequate and where expansion of system capacity may be mechanically unfeasible or too costly. Auxiliary air hoods are hoods that are provided with a source of air in addition to that taken from the room. It is essential that all air for these hoods be supplied from outside the hood face. Any model that introduces air behind the sash must not be used, because this arrangement reduces the control velocity at the face and could actually pressurize the work chamber if the exhaust flow is reduced (e.g., by foreign matter in fan, a broken belt, or normal wear and maintenance). Features described for the constant-volume bypass-type hood, including the bypass arrangement, are applicable to the auxiliary air hood. Auxiliary air supplies must be turned off to test the face velocity of the hood; a readily accessible means of turning off auxiliary air electrical power will facilitate such testing.

15.7.3 VARIABLE-AIR-VOLUME (VAV) HOODS

VAV hoods shall be installed as approved by the manufacturer or per the manufacturer's recommendation. The hood manufacturer, in conjunction with the control manufacturer, shall certify that the hood and laboratory system operation is as designed. Response times for reestablishing the proper face velocity after a maximum change in sash position shall not exceed 0.8 seconds. The minimum airflow through a VAV hood must meet or exceed 25 cfm per square foot of LFH work surface with the sash closed with four room air changes per hour for an unoccupied laboratory, or must be calculated to limit the accumulation of volatile vapors within the fume hood to less than 25 percent of their lower flammable limit. The minimum airflow during occupied hours will be capable of eight room air changes per hour in the laboratory. As an alternative to relying on minimum airflows for preventing accumulation of vapors, fume hoods, whose interior may be classified as described in NEC Article 500, and appropriate electric devices and equipment within the fume hood enclosure may be used. However, the minimum flows still must be capable of maintaining the laboratories at a negative air pressure relative to adjacent corridors and non-laboratory spaces. Refer to NFPA 45 for guidance on electrical classification of fume hood enclosures.

15.7.4 RADIOISOTOPE HOODS

Radioisotope hoods shall meet all the requirements of the fume hood types described above, except that the interior liner material shall have panels at the sides, back, top, and plenum enclosure of 18-gauge Type 302 stainless steel and structural members, reinforcements, and brackets of 16-gauge Type 302 stainless steel. The work surface should be 14-gauge Type 302 stainless steel. Joints should be fully sealed by welding or fine-line solder. The base structure should have a heavy angle frame reinforced to support 1 ton of lead brick shielding. The work surface shall be reinforced from the underside with heavy steel grating to provide the necessary strength for holding lead brick radiation-protection and/or shall be capable of supporting at least 200 pounds per square foot. To minimize radioactive emissions into the atmosphere, high-efficiency particulate aerosol (HEPA) filters should be considered as a best available control technology for radioactive isotope hoods. Guidance on the limitations, selection, and design of radioactive air-cleaning devices can be found in the *Nuclear Air Cleaning Handbook*, Energy Research and Development Administration (ERDA) 76-21, and in Nuclear Power Plant Air Cleaning Units and Components, ANSI/ASME N509.

15.7.5 PERCHLORIC ACID FUME HOODS

In addition to the features described for fume hoods, perchloric acid hoods must use materials that are nonreactive, acid resistant, and relatively impervious. Type 316 stainless steel with welded joints should be specified, although certain other materials may be acceptable. Corners shall be rounded to facilitate cleaning. Work surfaces shall be watertight with an integral trough at the rear for collection of wash-down water.

- Perchloric acid fume hoods shall be constant-volume bypass or VAV type with an average face velocity of 100 fpm +/- 10 FPM with sash 80% open.

- A wash-down system must be provided that has spray nozzles to adequately wash the entire assembly including the stack, blower, all ductwork, and the interior of the hood, with an easily accessible strainer to filter particulates in the water supply that might clog the nozzles. The wash-down system shall be activated immediately after the hood has been used.

- All welded ductwork shall be installed with a minimal amount of horizontal runs and no sharp turns; ductwork also must not be shared with any other hood.

- Exhaust fans must be of an acid-resistant, non-sparking (AMCA Standard Type A) construction. Lubrication shall be with fluorocarbon grease only. Gaskets shall be of a tetrafluoroethylene polymer.

- Perchloric acid must never be used in hoods not specifically designed for its use. Organic materials, strong dehydrating or desiccating agents, and oxidizing or reducing materials must not be used in a hood used for perchloric acid.

15.7.6 SPECIAL PURPOSE HOODS

Special purpose hoods are defined as any hood that does not conform to the specific types described above in this subsection. Special hoods may be used for operations for which other types are not suitable (e.g., as enclosures for analytical balances, gas vents from atomic absorption, or gas chromatography units). Other applications might present opportunities for achieving contamination control with less bench space or less exhaust volume (e.g., using the hoods as special mixing stations, sinks, evaporation racks, heat sources, and ventilated worktables). Special purpose exhaust hoods shall be designed in accordance with ANSI A9.2 and NFPA 45. Appropriate applications for specific types of special purpose hoods are described below.

- Canopy Exhaust (Capture) Hoods: These shall be provided as required for the removal of heat from specific laboratory apparatus, such as furnaces, ovens, and sterilizers, or as otherwise called for in the laboratory program. Refer to ACGIH's *Industrial Ventilation* for requirements and specifications for canopy hoods.

- Flexible Spot Exhausts (Snorkels): These shall be required to remove chemical fumes or heat from specific laboratory instrumentation, such as high-performance liquid chromatography (HPLC), gas chromatography/mass spectrometry (GC/MS), and atomic absorption (AA) units. Snorkels require an estimated exhaust rate of 100 to 200 cfm or a rate appropriate to the intended use.

- Gas Cabinets: Special exhaust cabinets will be required to house individual or pairs of toxic/pyrophoric gas cylinders. Leak detectors and low-exhaust flow alarms, as well as a gas purge system, shall be considered to provide for safe exchange of cylinders. Exhaust for these cabinets is estimated at 50 to 75 cfm each.

15.7.7 HORIZONTAL SASHES

Horizontal sashes, as well as other nonstandard features (larger-than-usual opening in distillation hoods, vented sinks, hoods larger than 6 feet), may be used under the following conditions. (It should be noted that horizontal sashes may put additional demands on VAV performance.)

- A conventional hood does not meet the specific requirements of the user (this should be reflected in the standard operating procedures).

- The hood is used as intended by the manufacturer (i.e., the hood is not altered after installation).

- The hood passes the pre-purchase performance test.

15.7.8 NOISE

The noise exposure at the working position in front of the hood shall not exceed 70 dBa with the system operating and the sash open, nor shall it exceed 55 dBA at benchtop level elsewhere in the laboratory room. Each new hood installation shall be certified as meeting this requirement before initial use and shall be recertified annually thereafter. Total room performance with respect to noise levels must not exceed the limits specified in 29 CFR §1910.95.

15.7.9 EXHAUST SYSTEM

Individual exhaust systems should be provided for each fume hood when the mixing of effluents from the individual hoods is inadvisable or when the effluent must be filtered, scrubbed, washed down, or otherwise treated before discharge. Pressure in laboratories shall be maintained as negative with respect to adjacent areas. Blowers should be rated and should be installed at the end of each duct system so that all ducts within the occupied areas of a building are maintained under negative pressure. Hood exhaust should be designed in accordance with the recommendations in ACGIH's *Industrial Ventilation*, ANSI Z9.5, and NFPA 45.

Fume hoods and general laboratory exhaust shall be routed to a stack discharge point at the highest area of the building roof line and shall be positioned to prevent entrainment of fumes at fresh air intake points. Fume hood exhaust stacks shall be constructed without caps or heads. Exhaust stacks should extend a minimum of 10 feet above the adjacent roof level and operate at a minimum of 3,000 fpm exhaust discharge velocity. The exhaust velocity may be lower than 3,000 fpm and the stack height lower than 10 feet if proven to prevent entrainment through performance of site atmospheric air flow characteristics and exhaust stack dispersion performance analyses as recommended in 1999 ASHRAE Application Handbook.

15.7.9.1 MANIFOLDING OF FUME HOODS

Manifolding of fume hood exhausts is allowed if a single discharge point is advantageous, and the air supply suitably controls comfort conditions while maintaining proper laboratory pressure. Manifolded exhaust systems should incorporate staged, multiple constant volume fans with control dampers to maintain a constant static pressure in the manifold in order to ensure quick response to changing hood conditions. Variable-speed fans are permitted if they are advantageous. In order for manifolded fume hoods to be safe, sufficient dilution of air within the ductwork must be maintained to avoid significant chemical reactions that may result in fire, corrosion, deposition, and/or increased toxicity. Low airflows afforded by VAV may increase the potential for significant reaction. Manifolding of fume hoods shall meet the requirements of NFPA 45.

Fume hoods, biological safety cabinets, and general laboratory exhaust may be combined in a commonly manifolded exhaust duct system for blocks of hoods; however, such combined systems require the prior approval of SHEMD. Provisions should be made for separate, dedicated duct and exhaust systems for special fume hood exhausts, including, but not limited to, perchloric acid hoods, high-energy radioisotope hoods, and exhausted biological safety cabinets, that cannot be combined in a commonly manifolded system. Hoods used for dissimilar purposes or hoods that are far apart from each other should not be manifolded.

15.7.10 EFFLUENT CLEANING

When air-cleaning devices are required, the type is determined by the contaminant and the degree of cleaning necessary. The type of air cleaner required can vary from a simple scrubber and filters to incinerators or specially designed units. All cleaning systems must be approved by AEAMB and SHEMD

A typical cleaning system consists of a prefilter, followed by a solvent-resistant HEPA filter, followed by an activated-charcoal filter. It is good practice to install a prefilter ahead of a HEPA filter to prolong the life of the HEPA filter. In some situations, bag-in/bag-out filter housings should be used to minimize the spread of contaminants when the HEPA or prefilter is changed. It is recommended that a compensating damper be installed with a HEPA filter so that the airflow will remain constant over the life of the filter. The resistance of HEPA filters to airflow, especially when airflow is loaded with contaminants, must be considered in designing a system with HEPA filters. The pressure drop across HEPA and prefilters should be monitored and alarmed, and filters changed when necessary. The filter plenum should be located on the inlet side of the fan to allow the fan to be serviced from the clean side of a filter. It is good practice to allow a straight run of 4 duct lengths before and after the fan in order to obtain good fan performance as well as to allow for future installation of other air-cleaning equipment.

15.8 Other Ventilated Enclosures

Ventilated enclosures are often required by a laboratory to help dissipate heat and ensure containment of chemical or biological airborne contaminants produced during certain work. These types of enclosures have special design requirements for their intended uses. Ventilated devices used to control hazardous materials must be individually approved by SHEMD and AEAMB. Ventilating devices used for removal of heat or nuisance odors must comply with the parameters set forth in ACGIH's *Industrial Ventilation*.

15.8.1 GLOVE BOXES

Glove boxes are often required by laboratory personnel to ensure containment of chemical and biological airborne contaminants produced during the employee's work in the box and to prevent escape of those contaminants into the room. Such enclosures permit manual manipulations within the box by means of armholes provided with impervious gloves, which are sealed to the box at the armholes. These types of enclosures shall comply with NSF Standard 49.

15.8.2 BIOLOGICAL SAFETY CABINETS

Laminar-flow biological safety cabinets shall meet minimum standards for cabinet classifications in NSF 49 for personnel, environmental, and product safety and shall be listed and identified by a distinctive NSF seal. Field recertification, performed by an NSF 49 listed competent technician and done according to the procedures outlined in NSF 49, will be required once the cabinet(s) is installed. Cabinet classification shall be determined during laboratory programming, in consultation with the users of the facility. These types of cabinets have special design requirements depending on their intended use (such as protecting personnel from harmful agents inside the cabinet; protecting the work product, experiment, or procedure from contaminants outside the cabinet; or protecting the laboratory environment from contaminants inside the cabinet) established by the end user and listed in the design criteria/POR.

15.8.3 FLAMMABLE LIQUID STORAGE CABINETS

Cabinets for the storage of Class I, Class II, and Class IIIA liquids shall be provided in accordance with the design, construction, and storage capacity requirements stated in NFPA 30, Chapter 4. Venting of storage cabinets is not required for fire protection purposes, but venting may be required to comply with local codes or authorities having jurisdiction. Nonvented cabinets shall be sealed with the bungs supplied with the cabinet or with bungs specified by the manufacturer of the cabinet.

If cabinet venting is required, the cabinet shall be mechanically vented to the outside in accordance with requirements of NFPA 30, Chap. 4 listed below:

- Both metal bungs must be removed and replaced with flash arrestor screens (normally provided with cabinets). The top opening will serve as the fresh air inlet.
- The bottom opening must be connected to an exhaust fan by a substantial metal tubing having an inside diameter no smaller than the vent. The tubing should be rigid steel.
- The fan should have a non-sparking fan blade and non-sparking shroud.
- The cabinet shall exhaust directly to the outside (the cabinet shall not be vented through the fume hood)
- The total run of exhaust duct should not exceed 25 ft (17.6 meters).
- The design velocity of the duct should not be less than 2,000 fpm per Table 3-2, *Industrial Ventilation, 22nd Edition.*
- The cabinets shall be marked in conspicuous lettering *"Flammable - Keep Fire Away."*

15.9 Air Filtration and Exhaust Systems

15.9.1 DRY FILTRATION

Air filters for ductwork and equipment installation shall be easily removable, serviceable, and maintainable. Air filters shall have face velocities as recommended by the filter manufacturer in order to achieve the specified efficiency at the lowest possible pressure drop. Filters shall be constructed of noncombustible materials that meet the requirements of UL 900, Class I. Air filters shall be located on the suction side of fans and coils and in other special locations as required for air treatment. Air-filter pressure drop gauges of the diaphragm-actuated dial type (preferred) or the inclined manometer type shall be located on all filter assemblies except small fan coils and fan-powered VAV terminal units. The ASHRAE dust spot method shall be used in specifying the efficiencies required for medium-efficiency filters. Filters shall be specified, and installed for use, as prefilters, medium-efficiency filters, or high-efficiency filters.

15.9.2 ABSOLUTE FILTRATION

Absolute filtration, where required in fume hood exhaust systems, will have an efficiency of 99.97 percent, as determined by the dioctyl phthalate (DOP) aerosol test for absolute filters and shall satisfy ASHRAE 52-76.

15.9.2.1 TEST ACCESS

The test access location shall facilitate in-place testing of HEPA filters, with particular attention given to plenum hardware that allows the HEPA filter bank to be tested without requiring the testing personnel to enter the plenum. Utility services shall be extended to the plenum location (e.g., electrical receptacles and compressed air) to facilitate testing work. In-place testing design requirements shall meet all the recommendations of UL 586 and ASME N510. HEPA filtration systems shall be designed with prefilters installed upstream of HEPA filters to extend the HEPA filter's life. The installation of prefilters may be omitted if an analysis of filtration requirements and consideration of the filter assembly justify omission.

15.9.2.2 FIRE PROTECTION OF HEPA FILTER ASSEMBLIES

In providing fire protection for the HEPA filters, the design shall sufficiently separate prefilters or fire screens equipped with water spray from the HEPA filters in order to restrict impingement of moisture on the HEPA filters. Under conditions of limited separation, moisture eliminators or other means of reducing entrained moisture shall be provided. Moisture eliminators may be omitted where system design provides sufficient filter redundancy to ensure continued effluent filtration in the event of fire within any portion of the system. The HEPA filter fire protection system shall be activated in a manner consistent with the fire protection system in the room or building in which the filters are located.

15.9.3 AIR-CLEANING DEVICES FOR SPECIAL APPLICATIONS

Filters include dry-type dust collectors, wet collectors, centrifugal collectors, absorbers, oxidizers, and chemical treatment filters, which are used primarily in industrial and process-type applications associated with air or gases that have heavy dust loadings in exhaust systems or stack gas effluents. Filters shall be designed according to the requirements given in the project criteria, the ASHRAE *Handbook of HVAC Systems and Equipment* and ACGIH’s *Industrial Ventilation*.

15.9.4 OPERATION

All building systems shall be designed for continuous operation, 24 hours a day, 7 days a week, unless otherwise specified in the project criteria. Additionally, night and weekend set backs are required.

15.9.5 MAINTENANCE ACCESS

The air supply and exhaust plenums shall be designed so that such elements as motors, bearings, control valves, and steam traps are easily accessible for maintenance.

15.9.6 LOCATION OF AIR INTAKE

The outside air intake(s) shall be located to provide the cleanest possible source of fresh air for the building and shall be so placed, relative to the building’s exhausts and vent stacks, as to prevent entrainment of contaminated air from outside sources, including, but not limited to, fume hood exhaust, vehicle exhaust, exhaust from adjacent structures, and sources of potential microbial contamination, such as vegetation, organic matter, and bird and animal droppings. Special care shall be exercised not to locate mechanical air intakes toward the loading dock area. Idling trucks located in loading dock areas may cause contamination of intake air. For security reasons, air intakes must be located in accordance with “Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks” DHHS (NIOSH) Publication 2002-139, May 2002.

15.9.7 AIR FLOW CHARACTERISTICS STUDY

The location and design of the exhaust stacks as well as the fresh-air intakes to avoid adverse air quality impacts shall be based on criteria developed by a study of prevailing wind patterns utilizing recognized wind modeling technology, such as the EPA Industrial Source Complex Model (ISC3) utilizing Briggs plume rise equations, and the design criteria of Chapter 16 of the 2001 ASHRAE Handbook, and Chapter 44 of the 2003 ASHRAE Handbook, as applicable. In addition, the study should take into consideration recommendations of Sect. 5.16, Exhaust Stack Outlets, including Figures 5-29 and 5-30, of *Industrial Ventilation*, 22nd Edition, as applicable.

15.10 Plumbing

15.10.1 GENERAL

The criteria in this section apply to plumbing systems (fixtures, supply piping, drain, waste and vent piping, service water heating system, safety devices, and appurtenances) inside the building and up to 5 feet beyond the building exterior wall. Plumbing shall comply with the National Standard Plumbing Code (NSPC) or local plumbing code, the ASHRAE handbooks, and ASHRAE standard 90. Access panels shall be provided where maintenance or replacement of equipment, valves, or other devices is necessary.

15.10.2 WATER SUPPLY

Type K copper tubing shall be used below grade. Type L copper tubing shall be used above grade. Polybutylene (PB) plastic pipe and tubing may be used in lieu of copper tubing above grade where not subject to impact damage or otherwise prohibited by the project criteria. For new systems, domestic water shall be supplied by a separate service line and not by a combined fire protection and potable-water service or a combined process water and potable-water system within the building.

- Fittings for Type K tubing shall be flared brass, solder-type bronze or wrought copper. Fittings for Type L tubing shall be solder-type bronze or wrought copper. Fittings for plastic pipe and tubing shall be solvent-cemented or shall use Schedule 80 threaded. No lead solder shall be used for copper pipe in potable-water systems.

- Stop valves shall be provided at each fixture. Accessible shutoff valves shall be provided at branches serving floors, fixture batteries for isolation, or at risers serving multiple floors. Shutoff valves also shall be provided to isolate equipment, valves, and appurtenances for ease of maintenance.

- Accessible drain valves shall be provided to drain the entire system. Manual air vents shall be provided at high points in the system.

- Provision for expansion shall be made where thermal expansion and contraction cause piping systems to move. This movement shall be accommodated by using the inherent flexibility of the piping system as laid out, by loops, by manufactured expansion joints, or by couplings.

- Accessible manufactured water hammer arresters shall be provided. Dielectric connections shall be made between ferrous and nonferrous metallic pipe.

- Where domestic water or fire protection service lines enter buildings, suitable flexibility shall be provided to protect against differential settlement or seismic activity, in accordance with the NSPC and NFPA 13, respectively.

15.10.2.1 METERING

All incoming water to an EPA facility shall be directly metered so that the total facility water consumption is measured and known. Facility subsystems, such as cooling towers and reverse osmosis equipment, that may consume a significant (10 percent or more) portion of the facility water intake, based on engineering calculation or estimate, shall be equipped with flow-totalizing sub-meters. Meters and sub-meters shall be calibrated and maintained according to the manufacturer’s specifications. Total metered and sub-metered water consumption shall be recorded and tracked at least monthly in a manner that allows facility operating personnel to identify and resolve any unusual or unexpected consumption.

15.10.2.2 LEAD IN POTABLE WATER

Potable water systems components, such as piping, valves, fittings, drinking fountains, and fixtures, shall conform with requirements of the EPA National Primary Drinking Water Regulations (NPDWR) for lead and copper, 40 CFR Parts 141 and 143. Components shall not be incorporated unless bearing the National Sanitation Foundation (NSF) Standard 61 mark signifying compliance with NPDWR requirements. Upon substantial completion of the building, the potable water system within the building as well as the potable water supply main shall be tested for lead content in accordance with EPA Publication entitled "Lead in Drinking Water in Schools and Residential Buildings," EPA 812-B-94-002, April 1994. Testing of the building potable water system and the potable water supply main shall be coordinated with the local water company as well as the state environmental protection agency.

15.10.2.3 STERILIZATION

New supply systems or existing supply systems that have undergone rehabilitation will require sterilization in accordance with American Water Works Association (AWWA) C652, AWWA C5186, or the local governing plumbing code.

15.10.3 DRAIN, WASTE, AND VENT LINES

Underground lines that do not service laboratory areas shall be service-weight cast-iron soil pipe hub-type (with gasket); hubless cast-iron soil pipe may be used in locations where piping is accessible. Aboveground (above grade) lines that are 1½ inches in diameter and larger shall be either hubless or hub-type (with gasket) service-weight cast-iron pipe. Lines that are 1½ inches through 6 inches in diameter may be acrylonitrile-butadiene-styrene (ABS) pipe where allowed by the project criteria. Pipe and fittings shall be joined by solvent cement or elastomeric seals. Lines that are less than 1½ inches in diameter shall be either (1) Type L copper with solder-type bronze fittings or wrought copper fittings or (2) galvanized steel with galvanized malleable iron recessed threaded and coupled fittings. Cast-iron soil pipe fittings and connections shall comply with Cast Iron Soil Pipe Institute (CISPI) guidelines. Provisions for expansion shall be included, as above.

Underground lines servicing the laboratory area shall be acid-resistant sewer pipe ANSI/ASTM D-2146-69; polyethylene plastic pipe and fittings, Schedule 80, ASTM D-1785; PVC plastic pipe, Schedule 80 and 120, ASTM D-2241; PVC plastic pipe (SDR-PR), ASTM D-2683; polypropylene fusion welded pipes, Schedule 80, and approved equal products; or socket-type polyethylene fittings for outside diameter-controlled polyethylene pipe. They shall be welded together following ANSI/American Welding Society (AWS) D1.1, structural welding code; ASTM D-2241; and ASTM D-2855.

15.10.3.1 TRAP SEAL PROTECTION

A trap primer valve and floor/funnel drain with trap primer valve discharge connections shall be used where there is the possibility of loss of the seal in floor/funnel drain traps.

15.10.4 BACKFLOW PREVENTERS

Backflow preventers of the reduced-pressure-zone type shall be provided on any domestic water and fire protection lines serving the building. All domestic water lines shall be provided with water hammer suppressors and vacuum breakers at high points of supply lines or at the fixture.

15.10.5 SAFETY DEVICES

Tempering valves shall be of the fail-safe pressure-balance type. Hot-water generation equipment shall be provided with ASME code-stamped tanks, when of sufficient capacity, water temperature, or hot input rate to be within the jurisdiction of the ASME Boiler and Pressure Vessel Code. Approved pressure-relief devices, such as combination temperature-pressure or separate units, depending on the application, shall be provided. Backflow preventers and air gaps shall be used to prevent cross-connection (contamination) of potable-water supplies. Vacuum breakers (to prevent back-siphonage) shall be used only in conjunction with administrative controls.

15.10.5.1 PRESSURE-REDUCING VALVES

Pressure-reducing valves shall be provided where service pressure at fixtures or devices exceeds the normal operating range recommended by the manufacturer. Wherever a pressure-reducing valve's failure may cause equipment damage or unsafe conditions, a pressure-relief valve shall be provided downstream of the reducing valve.

15.10.6 LABORATORY SAFETY DEVICES

Eye and face washing equipment and safety showers must be provided for every laboratory and laboratory support room where chemicals are being utilized, or stored, in accordance with the American National Standards Institute (ANSI) Standard Z358.1. The location and installation of emergency showers and eyewash equipment shall be in accordance with the *Safety Manual*. Discharge from emergency showers or eyewashes should not impinge on powered electrical equipment. Safety equipment must meet ADA accessibility requirements.

15.10.6.1 EMERGENCY EYEWASH UNITS

Emergency eyewash units or combination eyewash/safety shower units shall be provided in all work areas where, during routine operations or during foreseeable emergencies, the eyes of an individual may come into contact with a substance that can cause corrosion, severe irritation, or permanent tissue damage, or that is toxic by absorption. At least one eyewash, initiated by a single action, shall be provided within every laboratory, or for every two laboratory modules. Eyewash units shall be designed to flush both eyes (double-headed unit) simultaneously and to provide hands-free operation. The eyewash units chosen should provide protection of the nozzle area with pop-off covers, and other protective features to prevent contamination of the flushing system. Design, operation, flow, water temperature, and similar characteristics shall meet the criteria in ANSI Z358.1-1998. Water for the units shall be supplied by the potable-water system. The temperature of flushing fluid for the emergency units shall be tepid, 60-95 °F. Emergency eyewash units shall be provided with sanitary drains.

Eyewash units shall be in accessible locations that require no more than 10 seconds to reach. Their location in all laboratory spaces shall be standardized as much as possible. Units shall be placed in a location away from potential sources of hazard (e.g., fume hoods) and near the exit door. The location shall be well lighted and shall be clearly identified with a highly visible sign. Final location shall be approved by the EPA project officer during the design phase.

15.10.6.2 EMERGENCY SAFETY SHOWERS

Emergency safety shower units shall be provided in areas where, during routine operations or during foreseeable emergencies, areas of the body may come into contact with a substance that is corrosive, severely irritating to the skin, or toxic by skin absorption. Each safety shower unit shall be equipped with an installed flexible hand-held drench hose with a spray head like that used in hand-held eyewash units; this shall be mounted on a rack. All piping for the emergency safety showers shall be above the ceiling except for the shower head and the pull bar connection. Design, operation, flow rates, and similar characteristics shall meet the criteria in ANSI Z358.1-1998. Water for shower units shall be supplied by the potable water system. The temperature of flushing fluid for the emergency units shall be tepid, 60-95 °F. Rigid pull bars of stainless steel should be used to activate the shower and should extend to within 54 inches of the floor. The floor area of the emergency safety shower shall be textured, well lighted, identified with a highly visible sign, and maintained free of items that obstruct its use. A water flow alarm shall sound when the safety shower is activated.

Location of safety showers shall be standardized as much as possible. Emergency safety showers in laboratories shall be located at the room entrance on the right-hand side of the exit door (hinge side); instrument laboratories and laboratory support spaces shall have showers located in the corridor at the pull side of the room door. Safety showers shall be provided in accessible locations that require no more than 10 seconds to reach from hazard locations, preferably inside or just outside the door of each laboratory work area. Safety showers should be no more than 50 feet travel distance from the hazard source. Refer to Chapter 4 of the *Safety Manual* for additional information.

15.10.7 LABORATORY SERVICE FITTINGS

Laboratory service fittings for each laboratory space are specified in the room data sheets and shall be compatible with their intended use. All service valves, fittings, and accessories shall be of cast brass with a minimum copper content of 85 percent, except for items that are to be brass-forged or bar stock. All service valves, fittings, and accessories shall be especially designed for laboratory use. All laboratory service fittings shall have an acid-resisting and solvent-resisting clear plastic coating applied over a clean, polished, chrome-plated surface. Service fittings at fume hoods shall have an acid-resistant and solvent-resistant plastic coating applied over a fine sandblasted surface, properly cleaned.

15.10.8 GLASSWARE WASHING SINKS

Sinks dedicated to the purpose of washing laboratory glassware shall have a high or telescoping spigot with a swing-type gooseneck to accommodate large pieces of glassware. Large sinks shall be provided with a hand-held sprayer whose weight is supported for ease of operation. All glassware washing sinks shall be ventilated at a rate of 280 to 300 cfm with an exhaust air duct connection at the top of the sink below the bench top.

15.10.9 CENTRALIZED LABORATORY WATER SYSTEMS

The following requirements apply to laboratory water systems.

15.10.9.1 DEIONIZED WATER (DI) SYSTEM

Unless otherwise specified in the project criteria, the central deionized water system shall have a resistivity of greater than 10 megaohms at the tap in each laboratory. This system may be a centralized system or several decentralized systems depending on the requirements of the specific laboratory facility. Water quality shall conform to ASTM Type I requirements for reagent-quality water and to American Pharmaceutical Association (APhA) requirements for water used in microbiological testing. Type I water is typically prepared by reverse osmosis, then polishing it with mixed-bed deionizers and passing it through a 0.2-micron membrane filter. Pipes and fittings for the DI system shall be polyvinylidine fluoride (PVDF) schedule 80 or unpigmented polypropylene. A bypass or drain legs shall be provided at the lowest points in the piping system to avoid stagnation of water at the branch pipes during extended periods of non-use.

15.10.9.2 HOT AND COLD WATER, POTABLE

The laboratory potable-water supply shall be piped in Type K or Type L copper. Only potable water shall be used for emergency eyewash units and emergency showers.

15.10.9.3 INDUSTRIAL HOT AND COLD WATER, NONPOTABLE

The laboratory nonpotable-water supply, identified as industrial hot/cold water, shall be piped in Type K or Type L copper. Approved backflow prevention devices shall isolate the laboratory nonpotable water system from the potable-water system. Hot-water supply shall be insulated, and hot water shall be recirculated to conserve energy.

15.10.9.4 CULTURE WATER SYSTEM

Culture water system piping shall be of Schedule 80 unpigmented polypropylene and shall have no metal in contact with the water. The holding tank shall be lined with unpigmented polypropylene. Transfer pumps shall be of solid unpigmented polypropylene.

15.10.9.5 METERS

Special centralized laboratory water supply systems, such as deionized water, reverse osmosis water, or culture water systems shall be equipped with flow totalizing meters that measure total water consumption.

15.10.9.6 SIZING

Systems shall be sized to meet the needs of the facility. Designs should accommodate anticipated future growth through the ability to add modular additional capacity, rather than by providing initial overcapacity.

15.10.10 DRINKING FOUNTAINS

At least one drinking fountain shall be provided on each block of space so that no person will have to travel more than 150 feet to reach it. Self-contained mechanically refrigerated coolers shall be provided wherever a need for drinking fountains exists. Ratings shall be based on ARI 1010. Electrical equipment shall be UL listed. The refrigeration coils shall not be assembled using lead solder, and all components must bear the marking NSF 61indicating the components are free of lead. All drinking fountains and locations for drinking fountains shall comply with ADA.

15.10.11 TOILET FACILITIES

Separate toilet facilities for men and women shall be provided. The facilities must be located so that employees will not have to travel more than 150 feet to reach them. The toilet rooms' hot water should be set at 105 °F, or as required by the project criteria. Water closets and urinals shall not be visible when the toilet room entry door is open. All public toilet rooms shall be located along an accessible path of travel; must have accessible fixtures, accessories, and doors and adequate maneuvering clearances; and shall meet UFAS and ADA requirements.

15.10.11.1 TOILET SCHEDULE

Unless otherwise specified by EPA, each toilet room shall have a minimum of two for each men's toilet room and a minimum of four for each women's toilet room, enclosed with modern stall partitions and doors. Each men's toilet room should also have at least two urinals. The number of water closets in each women's toilet room shall be no less than the sum of water closets plus urinals of the adjacent men's toilet room. The number of water closets, urinals, and lavatories shall comply with all state and local codes and with project criteria. If a conflict exists between the project criteria and the state and local codes, the more stringent shall apply unless otherwise directed by the contracting officer.

15.10.11.2 ACCESSORIES

Each main toilet room shall contain:

- A soap dispenser, shelf, and mirror above the lavatory
- A toilet paper dispenser in each water closet stall
- A coat hook on the inside face of each water closet stall door and on the wall immediately inside the door of the toilet room.
- At least one modern paper towel dispenser and waste receptacle for every two lavatories
- A coin-operated sanitary napkin dispenser in women's toilet rooms
- Ceramic tile or comparable wainscot from the floor to a minimum height of 4 feet 6 inches
- A disposable toilet-seat-cover dispenser
- A convenience electrical outlet located adjacent to one mirror in each toilet room
- A small covered container located inside each water closet partition enclosure in the women's toilet room for the disposal of used sanitary napkins
- Toilet partitions made of recycled material.

The toilet room shall have at least one towel rack, towel dispenser, and other dispensers and disposal units mounted no higher than 48 inches from the floor, or 54 inches if a person in a wheelchair has to approach it from the side. One mirror with shelf shall be provided above the lavatory at as low a height as possible and no higher than 40 inches above the floor, measured from the top of the shelf and the bottom of the mirror. A common mirror provided for both the able and the disabled must provide a convenient view for both.

15.10.11.3 TOILET STALL ACCESSIBILITY

All toilet rooms designated for public access shall have one toilet stall that:

- Is 60 inches wide.
- Has a minimum depth of 56 inches when wall-mounted toilets are used or 59 inches when floor-mounted sets are used.
- Has a clear floor area.
- Has a door that is 32 inches wide and swings out.
- Has handrails on each side (front-transfer stall) or on the side and back (side-transfer stall). Handrails shall be 33 to 36 inches high and parallel to the floor, shall be 1 to 1½ inches in outside diameter, shall have 1½ inches of clearance between rail and wall, and shall be fastened securely at ends and center. Handrails shall have no sharp edges and must permit the continuous sliding of hands.
- Has a water closet mounted at a height of 17 to 19 inches, measured from the floor to the top of the seat. Hand-operated or automatic flush controls shall be mounted no higher than 44 inches above the floor.

A toilet stall measuring 36 or 48 inches wide by 66 inches, but preferably 72 inches, deep may be acceptable, as determined by EPA.

15.10.11.4 LAVATORY ACCESSIBILITY

At least one lavatory shall be mounted with a clearance of 29 inches from the floor to the top of the bottom of the apron. The height from the floor to the top of the lavatory rim shall not exceed 34 inches. Faucets shall be lever operated, push type, or electronically activated for one-hand operation without the need for tight pinching or grasping. Drain pipes and hot-water pipes under a lavatory must be covered, insulated, or recessed far enough so that individuals in wheelchairs who are without sensation will not burn themselves.

15.10.11.5 URINAL ACCESSIBILITY

Toilet rooms for men shall have wall-mounted urinals with elongated lips, with the basin opening no more than 17 inches above the floor. Accessible floor-mounted stall urinals with basins at the level of the floor are acceptable.

15.10.11.6 WATER-CONSERVING WATER CLOSETS, SINKS, AND LAVATORIES

Flow control devices shall be installed (unless otherwise dictated by the project criteria) on all water closets, sinks, and lavatories. Devices shall limit water closet flow to 1.6 gallons per flush, urinals to 1.0 gallon per minute, and regular lavatories to 1.5 gallons per minute. New lavatory faucets shall be equipped with automatic, sensor-operated shut-off valves. Automatic sensors shall be adjusted and maintained according to the manufacturer's specifications. Waterless urinals shall be considered whenever new facilities are built or renovations are made to an existing site.

15.10.12 SHOWER STALLS

Shower stalls shall be of fiberglass construction, complete with door, soap ledge, shower head, separate hot- and cold-water knobs, non-skid floor finish, and standard 2-inch floor drain. Shower stalls shall also provide a small change area with lockers. Emergency shower deluge heads shall not be used in regular shower stalls. Shower stalls shall conform with requirements of ADA and/or UFAS, as applicable.

15.10.13 HOSE BIBBS

Three-quarter-inch hose bibbs should be provided on exterior walls of the building(s), 30 inches above grade. At least one hose bibb shall be installed on each wall. When an exterior wall exceeds 75 feet in length, additional bibbs shall be installed so that distance between bibbs does not exceed 75 feet. Depending on the geographical location of the facility, the design professional shall use freeze-proof hose bibbs.

15.10.14 WATER CONSERVATION ELEMENTS AND TECHNIQUES

All significant water-using processes should be evaluated using the pollution prevention hierarchy of reduce, recycle, and reuse. Water use reduction should be considered as the first alternative. Each system shall be designed and operated in a manner that uses the minimum amount of water practicable. Within a system, water shall be recycled to the maximum degree practicable, prior to discharge. Water discharged from processes that require high quality water shall be considered for reuse in systems where the residual quality is sufficient for proper operation.

15.10.15 SINGLE PASS COOLING

Use of potable water for single pass cooling is prohibited. Acceptable replacements for single pass cooling are recirculated chilled water loops or point of use chillers.

15.11 Acid Neutralization System

All nonsanitary laboratory wastewaters are required to pass through an acid neutralization system to control pH as well as other chemical and/or material constituents, before discharging into a local publicly owned treatment works (POTW). The system shall be designed and constructed in accordance with 40 CFR 403.5, *National Pretreatment Standard Prohibited Discharges,* the National Pollutant Discharge Elimination System (NPDES), and the local POTW. The system shall have the capability of automatic, continuous monitoring and recording of wastewater discharge flow, pH, and other constituents to conform with POTW requirements. System components shall be accessible for monitoring, sampling, and maintenance. In addition, the system shall be provided with emergency power and an audible and visual alarm to alert staff in event of non-conforming discharges.

15.12 Laboratory Gases and Process Piping Systems

15.12.1 NONFLAMMABLE AND FLAMMABLE GAS SYSTEMS

Systems for flammable and nonflammable gas must meet the following requirements.

15.12.1.1 GENERAL

Special gas services for flammable and nonflammable gases shall be provided to all laboratories requiring their use. Gases shall be stored and piped in accordance with NFPA 45, *Fire Protection for Laboratories Using Chemicals*; NFPA 50A, *Gaseous Hydrogen at Consumer Sites;* NFPA 50B, *Liquified Hydrogen at Consumer Sites*; NFPA 54, *National Fuel Gas Code;* and NFPA 55, *Compressed and Liquefied Gases in Portable Cylinders,* as applicable. In situations not covered by NFPA code, the Compressed Gas Association (CGA) shall be consulted for guidance. No piping from any of these systems shall be run above or in the exit corridors.

- Gas cylinders for nonflammable gases, both in-use and standby, shall be manifolded from a remotely located space that is central to the laboratory areas and served by and accessible from the main storeroom or loading and receiving dock area. This space shall be designed and ventilated in accordance with code requirements.

- Flammable-gas cylinders shall be provided at the point of use only and shall be housed in ventilated cabinet enclosures mechanically ventilated to atmosphere with leak detection and alarm-monitoring devices.

15.12.1.2 DISTRIBUTION SYSTEMS

For all laboratories except metals analysis laboratories, a seamless-copper-piping gas distribution system for nonflammable gases shall be provided to all designated laboratories. Ideally, the length of the gas distribution lines should not exceed 100 feet to avoid the necessity for pipe joints. If pipe joints are required due to line length, prior approval by EPA is required. The process piping contractor shall propose proper sleeving. Regulator valves and other auxiliary equipment required to furnish gas at the required pressures shall be provided. Pipe sizes shall be coordinated to ensure proper velocity of the gas from the cylinders(s) to the point of application. The number and type of gas outlets in each room are indicated in the room data sheets. Exact and final outlet location in each laboratory must be approved by EPA during the design phase. The system design shall include a capability for individual room cutoff.

15.12.1.3 DISTRIBUTION TO METALS LABORATORIES

For all laboratories used for metals analysis, a seamless Teflon-piping gas-distribution system shall be provided. The lines shall be placed inside larger PVC pipes and vented to the outside of the building. Each line in this system shall be equipped at both ends with regulator valves and other auxiliary equipment required to furnish gas at required pressures. Gas-distribution systems other than Teflon may be utilized if approved by EPA. Pipe sizes shall be coordinated to ensure proper velocity of the gas from the cylinder(s) to the point of use.

15.12.1.4 BOTTLE GAS SUPPLY

The bottle gas supply shall be provided with duty and standby sets with automatic changeover valves and controls. For all gases, an indicator panel shall be installed close to the point of use in each of the laboratories. Rooms may be clustered in the panel as long as the distance between the point of use and the panel does not exceed 75 feet.

When toxic or explosive gases are used in a confined space, a multipoint gas analyzer and alarm system shall be provided to monitor concentration of the gases within this space. This system shall consist of gas sensors/transmitters, wiring, and a microprocessor-based monitoring-and-alarm control panel. The number and type of sensors/ transmitters shall depend on the specific application. Each sensor/transmitter shall transmit a frequency signal proportional to the gas concentration and shall have a special amplifier to eliminate the effects of radio frequency interferences. The control panel shall be capable of monitoring, and providing an alarm on, different types of gases in different zones; the panel shall have an audible and a visible alarm. The control panel shall also have a factory-wired terminal strip to interface with the energy management system for remote monitoring and alarms.

15.12.1.5 LIQUID NITROGEN AND LIQUID ARGON

Liquid nitrogen and liquid argon must be delivered to the point of use in liquid form. Insulation in the delivery system must be sufficient to prevent evaporation losses of liquid nitrogen. The gas distribution room for these two gases shall be as close as possible to the laboratory rooms where the gases are used—preferably adjacent to them. This gas distribution room shall also be directly accessible from the outside of the building without use of the laboratory corridors. One large tank for each gas shall be provided; each tank shall be permanently fixed in the room. The tanks shall be outfitted with necessary valves and controls, as required by the gas supplier.

15.12.1.6 NATURAL GAS DISTRIBUTION SYSTEM

Unless otherwise specified in the project criteria, each laboratory must have a natural gas distribution system.

15.12.1.7 TESTING AND PURGING

Before acceptance, the distribution system must be pressure tested and purged. The required level of purity specified at the point of use shall be maintained at all points in the system during testing and purging.

15.12.2 COMPRESSED-AIR SYSTEMS

When compressed-air systems are required, these systems should have oil and water traps, a dryer, and all controls. Unless otherwise specified in the project criteria, each compressed-air system shall have duplex compressors (one redundant) with an automatic lead/lag switch and a single compressor tank. Compressed-air systems for processes shall be completely independent of the compressed-air system for the HVAC controls. The compressed-air system shall provide a water trap and pressure regulation at each laboratory. An audible alarm and remote annunciation shall be provided to alert personnel to a loss of air pressure. Air compressors shall use vibration pads and springs, as needed, to substantially diminish vibration and sound generated by compressors. Further, compressor location should minimize transmission of vibration and sound to the building or rooms that the compressors service.

15.12.3 VACUUM SYSTEMS

When a laboratory vacuum system is required, it shall be composed of several vacuum pumps capable of evacuating air at a regulated suction of 25 inches of mercury or as specified in the project criteria. Storage volume and number of pumps shall be determined at the design stage as needed to meet laboratory benchwork requirements. Unless otherwise specified in the project criteria, each vacuum system shall have duplex pumps, an automatic lead/lag switch, and a single tank. An audible alarm and remote annunciation shall be provided to alert personnel to a loss of vacuum. Vacuum pumps shall use vibration pads and springs, as needed, to substantially diminish vibration and sound generated by the pumps. Further, pump location should minimize transmission of vibration and sound to the building or rooms that the pumps service.

15.13 Testing and Balancing

15.13.1 CONTRACTOR REQUIREMENTS

An independent air balance and testing agency that specializes in the balancing and testing of HVAC systems shall be used to balance, adjust, and test air-moving equipment and the air distribution system, water system, gas system, and compressed air-piping systems, as applicable. The independent contractor shall be an organization (1) whose specialty is testing and balancing environmental systems, (2) that is a member of the Associated Air Balance Council (AABC) or the National Environmental Balancing Bureau (NEBB), and (3) that has satisfactorily balanced at least three systems whose type and size are comparable to those of this project. The independent testing and balancing contractor shall be registered in the state in which the project is located.

15.13.2 SCOPE OF WORK

The testing and balancing (TAB) work shall include, but shall not necessarily be limited to, the following items:

- All air-conditioning supply and return systems
- Air exhaust systems

- Laboratory fume hood (LFH) supply and exhaust systems (including certification and performance testing of the laboratory fume hoods in accordance with *EPA Procedure for Certifying Laboratory Fume Hoods to Meet EPA Standards*)
- All hydronic systems
- Gas and compressed-air systems.

15.13.3 TESTING AND BALANCING PROCEDURES

The TAB procedures shall be in accordance with those prescribed by AABC or NEBB. The certification of the newly installed laboratory fume hoods requires use of test methods described in the ANSI/ASHRAE 110 "Method of Testing Performance Laboratory Fume Hoods" and the Scientific Equipment & Furniture Association, "Laboratory Fume Hoods Recommended Practices." The tests are modified to meet EPA standards and include:

- Measurement of cross draft velocities using a velocity anemometer located with the tip of the probe approximately 12 to 18 inches in front of the hood. Cross draft velocities should be measured parallel and perpendicular to hood face opening in front of the left, center and right sides of the hood.
- Measurement of face velocity with the vertical sash open 100 percent, 80 percent (design opening and height of mechanical sash stop) and vertical 6 inches open. The grid velocity measurements must be made using a velocity anemometer. Each grid velocity measurement should be recorded as the average velocity over a minimum of 10 seconds or ten readings per grid location.
- Smoke Visualization Tests at the 80% design sash opening. The smoke tests must include a low volume challenge and a high volume challenge.
- VAV Tests that measure flow response and stability in response to sash movements between 6 inches open and 80% open. The VAV tests are conducted by measuring face velocity or slot velocity in the baffle (variations in face velocity greater than 10 percent requires slot velocity measurement). A data logger is required to record face velocity data at a rate of at least 1 sample per second. The VAV tests consist of a 5 minute response test and two five minute stability tests. The response test is conducted by recording velocity while raising and lowering the sash three times during the 5 minute period. The sash is raised and lowered at a rate of approximately 1.5 ft/sec following the sash being lowered for 30 seconds and raised for 60 seconds. The stability tests are conducted by measuring velocity for five minutes at the 6 inch sash height and the five minutes at the 80% sash height.
- Recording of exhaust flow at the 6 inch sash opening and 80% sash opening. The flow rates are particularly important when slot velocities are measured and be verified against face velocity measurements.

The certification and/or performance testing of the LFH shall be performed by the fume hood manufacturer in presence of a SHEMD representative after the testing and balancing work has been completed, and the testing and balancing report submitted and approved by SHEMD. The TAB contractor shall be present and available to make needed adjustments during certifications and performance testing of LFHs by the LFH manufacturer. Criteria for the tests are summarized in Table 15.13.3.1.

Table 15.13.3.1 Testing Criteria for Newly Installed Laboratory Fume Hoods

Test	Criteria	Notes
Cross Draft Test	• $V_{cd} \leq 25$ fpm • Max ≤ 50 fpm	Sash 80% open
Face Velocity – 100% Open	• $V_{favg} = 80$ fpm • $V_{fmin} \geq 70$ fpm • $V_{fmax} \leq 90$ fpm	VAV hoods can have 100 fpm face velocity at 100% sash full open.
Face Velocity – 80% Open	• $V_{favg} = 100$ fpm • $V_{fmin} \geq 90$ fpm • $V_{fmax} \leq 110$ fpm	• Mechanical sash stop installed. • Monitor must indicate within 10% of actual face velocity.

Table 15.13.3.1 Testing Criteria for Newly Installed Laboratory Fume Hoods

Test	Criteria	Notes
Face Velocity – 6” Open	• Vf avg < 300 fpm for CAV hoods • Vfavg 100 fpm for VAV hoods	
VAV Response Test	Dynamic Sash Movement • DSSV6 ≥ 100 fpm (equivalent slot velocity) • DSSD6 ≤ 10% • DSSV80 = 100 fpm ± 10 fpm • DSSD80 ≤ 10% • DRT80 < 5 seconds • DRD80 ≤ 20%	• Average steady state velocity at 6 inches • Steady state deviation • Average steady state velocity at 80% open • Steady state deviation • Response time • Max deviation from average steady state velocity.
VAV Stability Test – 6 inch Opening	Stability Test • SSSV6 ≥ 100 fpm • SSSD6 ≤ 10% • QBAS6 ≥ 50 cfm/linear ft of hood width	Steady state velocity at 6 inch opening or equivalent Steady state deviation Reported flow at 6 inch opening
VAV Stability Test – 80% Opening	Stability Test • SSSV80 = 100 fpm ± 10 • SSSD80 ≤ 10% • QBAS80 ± 10% of design flow	Steady state velocity at 6 inch opening or equivalent Steady state deviation Reported flow at 80% opening

15.13.4 TESTING AND BALANCING DEVICES

HVAC air and water distribution systems shall be provided with permanently installed, calibrated testing and balancing devices, such as pressure gages, balancing valves, pitot tubes, dampers, thermometers, test holes, with access, as needed, to accurately measure and adjust water and air flows, pressures, and temperatures as required. At a minimum, the balancing devices in Table 15.13.4.1, Required Balancing Devices for Water and Steam Distribution Systems, and Table 15.13.4.2, Required Balancing Devices for Air Distribution Systems, shall be provided. Test devices shall be located and installed according to AABC Volume A-82.

Table 15.13.4.1 Required Balancing Devices for Water and Steam Distribution Systems

System Components (Water)	Required System Devices
Pump suction and discharge piping	Manifold pressure gauge with pressure taps
Pump discharge piping	Flow-measuring device (type depending on accuracy required) or inlet and discharge pressure gauges
Chiller evaporator water suction and discharge piping	Thermometer/test well; pressure gauge and gaugecock
Boiler or heat exchanger suction and discharge piping	Same devices as required for chiller evaporator piping
Heating or cooling coil (air-handling unit [AHU]) suction and discharge piping	Thermometer/test well; pressure gauge/pressure tap
Heating or cooling coil (AHU) discharge piping	Presettable calibrated balancing valve with integral pressure test ports
Reheat coil, fan coil unit, unit heater, ports, and finned tube radiation, convector: (1) discharge piping (2) suction piping	Presettable calibrated balancing valve with integral pressure test ports; temperature test; and pressure tap
Three-way control valves (each port) suction and discharge piping	Pressure tap
Boiler discharge piping	Flow-measuring device (orifice or venturi type)

Table 15.13.4.2 Required Balancing Devices for Air Distribution Systems

System Components	Required System Device
Diffusers, grilles, registers	Round butterfly or square/rectangular opposed-blade volume damper, either integral with device or in spin-in takeoffs
Branch ductwork runs	Rectangular/square or round (with more than one opposed-blade damper and terminal device). Sealed test hole for pitot tube traverse
Fan discharge ductwork	Sealed test holes for pitot tube traverse. Sealed test hole for static pressure measurements
Fan suction ductwork	Sealed test hole for static pressure measurement
Cooling coil suction and discharge airstreams	Duct-mounted airstream thermometer
Heating coil suction and discharge airstreams	Duct-mounted airstream thermometer
Mixed-air plenum airstream	Duct-mounted airstream thermometer

15.13.5 REPORTING

At the completion of the testing and balancing work, the testing and balancing contractor shall submit a report for EPA approval that conforms in format, and content to the requirements of AABC and/or NEBB The report shall reflect all aspects of the testing and balancing work, including a comparison of the adjusted/balanced performance of the systems with design requirements. The report shall be delivered at least 15 days prior to final inspection of the building.

15.14 Commissioning

Refer to Appendix B of this Manual for the commissioning requirements.

END OF SECTION 15

Section 16 - Electrical Requirements

16.1 General

16.1.1 CODE COMPLIANCE

All work done in this section shall comply with the applicable requirements of the most current edition of the following codes and references:

- National Electrical Code (NEC) (NFPA 70)
- National Fire Alarm Code (NFPA 72)
- Installation of Air-Conditioning and Ventilating Systems (NFPA 90A)
- Life Safety Code (NFPA 101)
- Emergency and Standby Power Systems (NFPA 110)
- Stored Electrical Energy Emergency and Standby Power Systems (NFPA 111)
- Lightning Protection Systems (NFPA 780)
- Factory Mutual (FM) Engineering Loss Prevention Data Sheet 5-4, Transformers
- 29 CFR §§1910.303-305
- *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*, National Research Council
- Title III Standards for the Americans with Disabilities Act (ADA) and Uniform Federal Accessibility Standards, sections 2, 3, 4, and 4a, respectively, of the Architectural Barriers Act of 1968, as amended
- NACE International Standards
- Standards of the National Electrical Manufacturers Association (NEMA)
- American National Standard Institute (ANSI)
- National Electrical Safety Code (NESC)
- Illuminating Engineering Society of North America (IES) Lighting Handbook
- Insulated Power Cable Engineers Association (IPCEA)
- Institute of Electrical and Electronics Engineers (IEEE) standards
- PBS-P100, *Facilities Standards for the Public Building Service*.

In addition, all work must comply with all applicable federal, state, city, and local codes, regulations, ordinances, publications, and manuals. All newly manufactured equipment shall be listed by Underwriters Laboratories Inc. (UL) or a similar testing laboratory acceptable to EPA. When codes conflict, the most stringent standard shall govern.

16.1.2 ELECTRICAL INSTALLATIONS

Electrical installations shall maintain the integrity of fire stopping, fire resistance, fire separation, smoke control, zoning, and other structurally oriented fire safety features in accordance with NFPA 70 and NFPA 101.

16.1.3 ENERGY CONSERVATION IN DESIGN

After careful study of the facility's requirements as well as of the day-to-day operation of its various departments, the design professional shall design systems that meet facility operating requirements in an energy-efficient manner. The health and safety aspects of the operation must retain first priority, however, and cannot be relaxed or traded off for more efficient systems. System and lighting design shall comply with the requirements of American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) standard 90, IES Lighting Handbook, the *Facilities Management and Services Division (FMSD) Energy Conservation Planning Handbook*, EPA’s Energy Star Program, and any state or local energy conservation codes or recommendations.

16.1.3.1 LOCAL ENERGY CONSERVATION PROGRAMS

The local utility company shall be contacted to find the latest information on any and all energy conservation programs in effect sponsored by the utility company. The economic validity of pursuing these programs shall be presented to EPA with the first design submittal, and if the programs are deemed viable, they shall be incorporated into the design for the project. The design professional, with EPA, shall pursue rebates and other assistance to install energy conserving equipment, if applicable.

16.1.3.2 LOAD SHEDDING/PEAK SHAVING

The payback and attributed atmospheric admissions involved in introducing a load-shedding/peak-shaving system into the facility design shall be evaluated. If a preliminary evaluation indicates a payback of 5 years or less, a detailed evaluation of load shedding/peak shaving systems for the project shall be prepared and submitted to EPA for funding consideration. The operational duty ratings of the systems evaluated and proposed is of utmost importance. Continuous duty operation equipment is required. Factors such as the various fuel sources, exhaust fume contribution to outdoor air quality, local air quality standards, and energy-efficient generator equipment shall also be considered.

16.1.3.3 DEMAND-SIDE MANAGEMENT SYSTEM

A demand-side management system to keep the peak demand of the facility below a predetermined level shall be evaluated. An economic analysis to determine the payback on such a system shall be performed. This system, if feasible, shall have the capability to follow the demand variations as an operator manually switches the loads.

16.1.4 COORDINATION OF WORK

A coordinated set of documents (i.e., coordination between architectural; electrical; heating, ventilation, and air-conditioning [HVAC]; plumbing; equipment; and structural systems for bidding) shall be provided. Documentation shall clearly identify the division of work among the trades and delineate the coordination responsibilities of the contractor. Special attention shall be given to designed-in equipment and equipment to be provided by the facility occupants.

16.1.5 POWER FACTORS

The design professional shall design the facility's electrical system so as to assure that the overall power factor of the entire electrical installation is a minimum of 90 percent. This power factor may be achieved by selection of electrical utilization equipment with individual power factor ratings that would render the required facility power factor or through the installation of power factor correction devices to meet the overall facility power factor requirement. The design professional shall assure that certain groups of inductive type loads, such as motors of 5 HP and above, fluorescent lighting fixtures, transformers, etc., are equipped with power factor correction at an individual level so that combined, the overall facility power factor will be attained. All required power factor correction devices shall be switched with the utilization equipment unless doing so results in an unsafe condition.

16.1.6 HANDICAPPED ACCESSIBILITY REQUIREMENTS

The facility shall also comply with the electrical requirements of the Uniform Federal Accessibility Standards (UFAS) (1984), adopted by the General Services Administration (GSA) in 41 CFR Parts 101-19.6, as well as with ADA and all state and local laws and standards for buildings and facilities that must be accessible and usable by physically handicapped people. The most stringent of these codes shall apply.

16.1.7 MATERIAL AND EQUIPMENT STANDARDS

All specified materials and equipment shall be standard products of manufacturers that are regularly and currently engaged in production of such items. Items that are obsolete or to be discontinued by the manufacturer, as well as materials and equipment of an experimental nature (or products that would be installed in a facility for the first time with this project), are not acceptable and will not be permitted. All material and equipment shall be specification grade, new, free from defects, and high quality, and shall be entirely suitable for these specific facilities.

16.1.8 ENVIRONMENTAL REQUIREMENTS

Careful consideration shall be given in the design to the types of materials to be used for the project as they relate to the environment in which they will be installed. Exterior equipment may be subject to different types of corrosive atmospheres and environments. Interior equipment in laboratories and testing and storage areas may also be subject to corrosive conditions. All equipment and material shall be suitable for the environment in which it will be installed. Noise mitigation shall be provided for equipment such as transformers and generators. Environmental considerations for electrical raceways and enclosures are further discussed in paragraph 16.13 of this section.

16.2 Primary Distribution

16.2.1 DUCTBANKS AND CABLE

All primary electrical distribution at new sites shall be underground. Underground cables should be preferably installed in conduit; however, very long cable runs may be installed where the cost of installing cables in conduit is extremely high. A cost comparison between direct burial cables and cables installed in conduit shall be submitted to the Project Officer for approval within ten (10) calendar days after contract award. The minimum conduit size for primary voltage cables shall be 4 inches. On multiple conduit ductbanks for primary distribution systems and for the emergency power distribution system up to the emergency distribution switchgear, 25 percent and not less than one (1) spare empty conduit shall be provided. Spare empty conduits for other critical equipment feeders, like the central HVAC equipment, shall be provided as directed by the POR or the Project Officer.

16.2.1.1 DUCTBANK ENCASEMENT

All underground cables and wires shall be installed in conduit. Underground conduit for circuits rated 600 volts or higher shall be encased in concrete. Multiple ductbanks where the heat produced by adjacent circuits affect the current carrying capacity of each individual circuit shall be encased in concrete.

16.2.2 SWITCHES

When a new campus-type utility distribution system or an extension of an existing campus-type distribution system is a part of the project, a loop system shall be considered. This system shall have sectionalizing primary switches. Primary switches shall be of load break design. All switches shall be pad mounted and lockable. Enclosures for switches shall be suitable to the environment in which the switches will be located. Where switches are to be located indoors, they shall be physically isolated from any emergency electrical equipment and shall be located in electrical rooms only.

16.2.3 OVERHEAD POWER SUPPLY LINES

Overhead power supply lines can be used only where service is to be installed in remote or unsettled areas, industrial areas, or areas where underground service is not feasible. Maximum use shall be made of single-pole structures. Overhead power supply lines may also be used for feeders to small single-phase loads or buildings. Careful consideration shall be given to the location of overhead lines in relation to future land use.

16.2.3.1 POWER AND COMMUNICATION POLES

Joint use of poles for power and communications distribution shall maintain safety standards and shall limit electrical interference to communications services. In joint use of poles, either for multiple electrical distribution systems or for both electrical distribution and communication lines, underbuilt lines or cables shall be of vertical construction. Use of double-stacked cross run construction shall be allowed only where proper clearances for hot-line maintenance work can be ensured. Clearances shall comply with the National Electrical Safety Code (NESC) [American National Standards Institute (ANSI) standard C2].

16.2.4 TRANSFORMERS

Transformers shall be located and installed in accordance with NEC Article 450 and in such a way as to minimize the fire and contamination hazards to the EPA facility and its occupants. The following requirements also apply:

- Whenever any public utility transformer or other equipment involves a dielectric fluid that is combustible, toxic, or otherwise hazardous, it shall not be located inside an EPA facility.

- Utility transformer vaults or transformer locations abutting an EPA building shall conform to the requirements of the NEC. Transformer equipment shall not be located adjacent to, or directly beneath, any exit.

- Transformers, fluorescent ballasts, and other electrical devices containing polychlorinated biphenyls (PCBs) shall not be used in EPA facilities.

- All transformers located within an EPA building shall be dry-type only (unless they are located within a transformer vault and furnished with a liquid confinement area and a pressure relief vent).

16.2.4.1 DRY-TYPE TRANSFORMERS

Dry-type transformers shall be provided with four 2.5 percent taps, two above and two below rated primary voltage. All transformers shall be designed for continuous operation; the insulation for dry type transformers shall be class “H.” All transformers shall conform to the design, temperature-rise, testing, and other requirements specified by the Acoustical Society of America (ASA), NEMA, and IEEE standards and shall have a rated sound level of 45 decibels (dBA) or below. To ensure against objectionable levels of noise being transmitted through the building, the dry-type transformers shall be mounted on approved vibration-isolation mountings. Connection to transformers shall be made with flexible steel conduit (Greenfield) with grounding jumper. All dry-type transformers shall be designed for nonlinear loads and shall be isolated-type transformers. They shall be K-rated and shall be shielded and located as close as possible to the load. The designer shall consider the use of shielded isolation transformers for sensitive computer and other electronic equipment loads.

16.2.4.2 OUTSIDE SUBSTATIONS AND TRANSFORMER INSTALLATIONS

In addition to the requirements above, outside substations and transformers meet the most current requirements of Article 450 of the NEC and applicable local utility company substation construction standards.

16.2.5 SYSTEM REDUNDANCY

A risk/benefit analysis should be performed to justify added capital costs for system redundancy.

16.3 Service Entrance

16.3.1 GENERAL

All service entrance equipment shall be UL listed for use as service entrance equipment. All components shall be factory wired for switchboards, panelboards, or unit substations before shipment. Service entrance equipment shall be physically isolated from all emergency power systems so that a failure in either system will not affect the operation of the other system. All service switchboards shall have factory-installed ammeters and voltmeters.

16.3.2 OVERHEAD SERVICES

Overhead services to buildings should not be used except in particular circumstances where underground services are not feasible, and then only with approval of the EPA contracting officer’s representative (COR). Where electrical service to the building is by overhead lines, proper dip poles, weatherheads, and supports shall be provided. The main service switch, panelboard, or switchboard shall be located immediately adjacent to the entrance of feeders into the building. Code-required clearances shall be maintained under all overhead lines. The openings necessary for bringing conductors into buildings shall be grouted or otherwise fire-stopped.

16.3.3 UNDERGROUND SERVICES

All underground secondary (voltage less than 600) conductors shall be installed in direct buried conduits. Where secondary-service reliability is a prime consideration, secondary service ductbanks shall be concrete encased. Minimum duct size of service entrance ducts shall be 4 inches, all other secondary conduits that might be necessary for power distribution to exterior lighting and other electrical loads shall be sized based on conduit fill as calculated in accordance with the latest edition of the NEC. A minimum of 25 percent spare service entrance ducts (but not less than one spare duct) shall be provided. Spare ducts shall be plugged or capped to prevent contamination. The locations where manholes (if required) are to be included shall be investigated to ensure that they will drain properly.

16.3.4 SERVICE CAPACITY

Incoming transformers must be provided, as required, and must be of sufficient capacity to accommodate the full design load plus 30 percent. To the greatest extent possible, public utility transformers shall be located outside of the actual building. If public utility transformers must be located within buildings because of site constraints, they shall be installed in standard transformer vaults conforming to the requirements of the NEC. These vaults shall not be located adjacent to, or directly beneath, any exit from the building. In calculating the design load, a demand factor of 100 percent should be used for lighting and fixed mechanical equipment loads and a demand factor of 75 percent for all other loads. The incoming service shall have sufficient capacity to accommodate the full design load plus 30 percent additional capacity for future growth.

16.3.5 METERING

Where medium voltage power is brought to the facility, electrical energy metering (kilowatt hour [kwh]) shall be furnished at each substation of 500 kilovolt-ampere (kVA) or greater capacity. Demand metering (kilowatt demand [kwd]) shall be furnished as required for load management. The economics of primary metering and secondary metering for campus-type facilities shall also be investigated; the most cost-effective method shall be used. Coordination with the local utility company should be performed to determine points of utility metering requirements. Single metering is preferred. Sub-metering of lighting and equipment in individual buildings is encouraged to monitor and adjust energy performance.

16.3.6 SERVICE ENTRANCE EQUIPMENT

Service entrance equipment shall consist of a main switch or switches, a main circuit breaker or circuit breakers, or a main switchboard or panelboard. In determining whether the service entrance equipment should be of the fused or circuit breaker type, careful consideration shall be given to the short-circuit current available at various points in the proposed distribution system.

16.3.5.1 SPECIFIC REQUIREMENTS

All service entrance equipment shall have copper busing. If the main service consists of a switchboard or panelboard, it shall have at least 10 percent of the switchboard rating as spare breaker or switches and 20 percent of the rating as bused spaces. The electrical system shall be properly coordinated for selective tripping in order to permit removal of only that portion of the system that has experienced a fault or overload condition.

16.3.5.2 RENOVATION

If this project is a renovation or an extension of an existing building, the history of the loads shall be carefully studied to ensure that the existing service entrance equipment has sufficient capacity to handle the loads of the addition or renovation and has spare capacity for future loads.

16.4 Interior Electrical Systems

16.4.1 BASIC MATERIALS AND METHODS

Electrical systems shall be designed so that all components operate within their capacities for initial and projected loads. Preferred standard voltages (per ANSI C84.1) shall be used, with a single voltage level characteristic in any classification, in order to minimize stocks of spare equipment and to standardize operating and maintenance practices and procedures. On-site acceptance testing shall be required for each major electrical system. Tests shall be performed in the presence of EPA personnel. Copies of all test results shall be submitted for approval. All receptacles, switches, and wiring devices shall be specification grade. All safety switches shall be heavy duty. All equipment shall be new and shall be installed and used in accordance with any instructions included in the listing or labeling as required and acceptable to EPA (i.e., UL listing or other EPA acceptable listing).

The design of the electrical distribution system (both normal and emergency power) shall take into account the effects that harmonics from nonlinear loads can produce on the system. Harmonics from nonlinear loads can affect the capacities of the neutral conductor, panelboards, phase conductors, and emergency generators. “K” rated transformers shall be used where the associated panelboards are feeding a large quantity of nonlinear loads. Special attention shall be given to the harmonics produced by variable-speed and variable-frequency drive units used for control of HVAC equipment.

16.4.2 CONDUCTORS

All conductors (wire and cable) shall be copper. All conductors for systems operating at 480 volts and below shall have 600-volt insulation with distinctive markings, as required by UL, for identification in the field. All conductors shall be continuous, without splices. All conductors operating at 600 volts and above shall be insulated and shall have the appropriate voltage and insulation ratings as required by their location in the system and in the facility. Branch circuit wiring shall not be smaller than No. 12 American Wire Gage (AWG). All conductors shall be color coded to identify each phase and the neutral. The grounding conductor shall be green or bare.

16.4.3 RACEWAYS

All electrical wiring shall be installed in conduit or raceway or shall be otherwise physically protected in accordance with the NEC. Conduit shall be at least ¾ inch.

16.4.3.1 SERVICE ENTRANCE CONDUIT

Service entrance conduit shall be provided as permitted by the NEC for the intended purpose. Service entrance conduits shall be enveloped in a minimum of 2 inches of concrete encasement. An empty conduit shall be provided up to the service entrance disconnect.

16.4.3.2 FLEXIBLE-METAL CONDUIT

Liquid-tight flexible-metal conduit shall be used for connections to meters, transformers, pumps, and other equipment, as required by the NEC and local codes, where vibration or movement can be a problem and where there is a need for protection from liquids, vapors, or solids.

16.4.3.3 RATED ASSEMBLIES

Raceways that penetrate fire-rated assemblies shall be noncombustible. Openings shall be sealed to maintain the established fire ratings as defined by UL.

16.4.3.4 SURFACE METAL RACEWAYS

Surface metal raceways shall be used to provide receptacles with power and for low-potential services (e.g., data and telecommunications wiring) in the laboratories themselves. The design professional shall review and make recommendations to EPA concerning the type of surface metal raceways appropriate to the project. The design professional shall consider using single-compartment surface metal raceways (2⅝ inches high by 1¾ inches deep, minimum size) where only power receptacles are required and double-compartment surface metal raceways (4¾ inches high by 2¼ inches deep, minimum size) where both power receptacles and telecommunications/data outlets are required. Raceway covers shall be precut to 12-inch sections. The raceway shall be divisible into two or three separate wiring components to facilitate installation of power or low-potential wiring. The material and color of the raceway shall be appropriate to the atmosphere in which the raceway will be installed.

16.4.3.5 PLENUMS, DUCTS, AND OTHER AIR-HANDLING SPACES

All wiring shall be in accordance with NEC Article 300, except that communication circuits (Article 800) and Class 2 and Class 3 circuits (Article 725) need not be run in conduit when conductors are of materials that are classified by UL as having adequate fire-resistant and low smoke-producing characteristics.

16.4.4 NEUTRAL CONDUCTOR

The neutral conductors of four-wire system feeder(s), directly serving nonlinear load shall be sized at double the ampere rating of the phase conductors through the entire interior electrical distribution system. The neutral conductors of 480/277-volt, four-wire feeders serving the lighting panels that control the electronic ballast fluorescent fixtures shall be sized at double the wire size of the phase conductors. Neutral conductors of circuits serving nonlinear load shall be dedicated to the circuit only. Therefore, when there is more than one circuit in a single conduit run and any of the circuits are serving nonlinear load, a dedicated neutral wire for each of the circuits serving nonlinear loads, in addition to the neutral wire serving the other circuits, shall be provided.

16.4.5 PANELBOARDS AND CIRCUIT BREAKERS

Panelboards shall comply with UL 50 and UL 67. Panelboards for use as service-disconnecting means shall also conform to UL 869A. Panelboards shall be equipped with a main circuit breaker and all branch circuit breakers as required. Design shall be such that any individual breaker can be removed without disturbing adjacent units and without loosening or removing supplemental insulation supplied as a means of obtaining clearances as required by UL. Where “space only” is indicated, provisions should be made for the future installation of a breaker, which shall be sized as indicated. All panelboard locks included in the project shall be keyed alike. All distribution panels serving fluorescent fixtures, laboratory room distribution panels, and any other panels serving nonlinear load shall be UL listed and labeled for nonlinear loads. An isolated neutral bus shall be provided in each panel for connection of circuit-neutral conductors. A separate ground bus marked with a yellow stripe along its front and bonded to the steel cabinet shall be provided for connecting grounding conductors. A separate ground bus marked with a green strip along its front and isolated from the panel cabinet shall be provided for connecting isolated insulated ground wires.

16.4.5.1 DIRECTORIES

Directories shall be provided to indicate the load served by each circuit. These directories shall be typed and shall be mounted in a holder behind a transparent protective covering. Bus board shall be supported on bases independent of the circuit breakers. Main buses and back pans shall be designed so that breakers may be changed without machining, drilling, or tapping.

16.4.5.2 CIRCUIT BREAKERS

Molded-case circuit breakers shall conform to NEMA AB 1 and UL 489 and UL 877 for circuit breakers and circuit breaker enclosures located in hazardous (classified) locations. Circuit breakers shall be thermal magnetic type with an interrupting capacity of 10,000 amperes symmetrical minimum.

The design professional is required to submit for approval by the EPA, short circuit calculations; if these calculations indicate that a higher circuit breaker interrupting capacity is required, then circuit breakers with the calculated interrupting capacity shall be provided. Breaker terminals shall be UL listed as suitable for the type of conductor provided. Plug-in circuit breakers are not acceptable. Common trip-type multiple breakers with a single operating handle shall be provided. Breaker design shall be such that an overload in one pole automatically causes all poles to open. Phase sequences should be maintained throughout each panel so that any adjacent breaker poles are connected to phases A, B, and C, respectively. Circuit breakers should be provided with ground fault interrupter as required by the NEC and in conformance with UL 1053. In addition, ground-fault circuit interrupter circuit breakers should be provided with a push-to-test button, visible indication of tripped condition, and an ability to detect a current imbalance of approximately 5 milliamperes.

16.4.5.3 SHUNT TRIP BREAKERS

Shunt trip main breakers shall be provided in panelboards to remove power to laboratory modules upon activation of fire protection systems or devices and emergency power off (EPO) button(s) in the immediate lab module. Shunt trip branch circuit breakers may also be required in order to remove power to other specific areas or equipment (e.g., to elevators with equipment room protected by a sprinkler system, computer rooms protected by sprinkler systems). It shall be the responsibility of the design professional to consult with the EPA very early in the electrical design (such as during the conceptual design phase) to enable the EPA to indicate and designate where shunt trip breakers are required in each specific facility that is being designed. <u>Note: The activation of a fire sprinkler head in an individual laboratory module is required to shutdown the power to that laboratory module. This power shutdown may be accomplished through the use of shunt trip breakers in the power panels.</u>

16.4.5.4 LABORATORY MODULE

Each laboratory module shall be provided with a separate 120/208-volt, three-phase, four-wire panelboard. The branch circuit system shall be as flexible as possible to accommodate any type of laboratory alteration. In addition, each laboratory module shall be provided with emergency power from an emergency power panelboard; the emergency power panelboard may serve more than one module. The panelboard should be rated for nonlinear loads. Each lab module shall be provided with UPS power from a UPS power panelboard. The UPS power panelboard may serve more than one lab module.

16.4.5.4.1 EMERGENCY POWER OFF (EPO) BUTTON

Each laboratory module and computer rooms protected by sprinkler systems shall have an EPO button by each main exit into the corridor. Activation of the EPO button shall shut down the power to the normal power panelboard for the laboratory module. The EPO button shall simultaneously shut down the power of each emergency circuit into the lab module and each UPS circuit into the lab module. The EPO button should activate the appropriate circuits via shunt trip breakers in the normal, emergency, and UPS power panels. The design professional should confirm with EPA early in the design if any HVAC components or equipment are required to be shutdown or required to provide a reduced air flow in the lab module when an EPO button is activated

16.4.6 MOTOR CONTROLLERS AND DISCONNECTS

Motor controllers and starters shall be provided for all motors and equipment containing motors. All controllers shall have thermal-overload protection in each phase. Solid-state motor controllers shall have undervoltage protection when used with momentary-contact pushbutton stations or switches and shall have undervoltage release when used with maintained-contact pushbutton stations or switches.

When used with a pressure, float, or similar automatic-type or maintained-contact switch, the controller shall have a hand-off-automatic selector switch. Connections to the selector switch shall be such that only the normal automatic regulatory-control devices will be bypassed when the switch is in the "hand" position. All safety control devices, such as low- and high-pressure cutouts, high-temperature cutouts, and motor-overload protective devices, shall be connected in the motor circuit in both the "hand" and the "automatic" positions. Control circuit connections to any hand-off-automatic selector switch or to more than one automatic regulatory-control device shall be made in accordance with a manufacturer-approved wiring diagram. The selector switch shall be capable of locking in any position.

For each motor that is not in sight of the controller, either the controlled disconnecting means shall be capable of being locked in the open position or a manually operated, nonfused switch that will disconnect the motor from the source of supply shall be placed within sight of the motor location.

Overload protective devices shall give adequate protection to the motor windings, shall be of the thermal inverse-time-limit type, and shall include a manual-reset pushbutton on the outside of the motor controller case. The cover of a combination motor controller and manual switch or circuit breaker shall be interlocked with the operating handle of the switch or circuit breaker so that the cover cannot be opened unless the handle of the switch or circuit breaker is in the off position. Variable-frequency drive units shall be considered for larger HVAC equipment loads, and for other motor loads as feasible. See Section 15, Mechanical Requirements, of this Manual for equipment to be used with variable-speed drives.

16.4.6.1 CONTROL EQUIPMENT

Control equipment shall comply with the National Electrical Manufacturers Association (NEMA), Industrial Controls and Systems (ICS) standards, NFPA 70 (NEC), and with UL 508. Single-phase motors may be controlled directly by automatic control devices of adequate rating. Automatically controlled polyphase motors and all polyphase motors rated greater than 1 horsepower (hp) shall have magnetic starters. Control devices shall be of adequate voltage and shall have an adequate current rating for the duty to be performed. Pilot control circuits shall operate with one side grounded and at no greater than 120 volts. Where control power transformers are required, they shall be located inside the associated motor starter housing, shall be protected against faults and overload by properly sized overcurrent devices, and shall be of sufficient capacity to serve all devices connected to them without overload. Reduced-voltage starters or variable frequency drives (VFDs) shall be provided for larger motors to avoid an unacceptable voltage dip when the motors are started. As a minimum, reduced voltage starters shall be required when the locked rotor current of motors exceeds the full-load of supply transformers or supply conductors.

16.4.6.2 SAFETY DISCONNECT SWITCHES

Safety disconnect switches shall be provided for all hard-wired electrically operated equipment and motors in locations where they are required by code. Switches shall meet the requirements of NEMA Type HD. Enclosure shall be NEMA 1 for indoor use and NEMA 3R for exterior use. All safety switches shall be horsepower rated. The switches shall be of the quick-make quick-break type, and all parts shall be mounted on insulating base to permit replacement of any part from the front of the switch. All current-carrying parts shall be of higher rated load without excessive heating. Contacts shall be plated to prevent corrosion and oxidation and to ensure suitable conductivity.

16.4.6.2.1 GROUND FAULT PROTECTION OF EQUIPMENT

With the exception of emergency systems, systems carrying 150 volts or greater to ground and not exceeding 600 volts phase-to-phase shall be provided with ground fault protection for each service-disconnecting means rated 1,000 amperes or more. Necessary precautions shall, however, be taken to minimize the possibility of nuisance tripping. In addition, all buses or other conductors at motor control centers, switchgear, switchboards, and busways shall be insulated or isolated. The facility may have special requirements with respect to ground fault protection on the main switchboard (such as two levels of ground fault). Very early in the design phase (such as during the conceptual design submittal phase), it shall be the responsibility of the design professional to consult with EPA concerning any special requirements above those required by the NEC. All special ground fault requirements above those required by the NEC shall be incorporated into the facility design.

16.4.6.2.2 GROUND FAULT CIRCUIT INTERRUPTER PROTECTION FOR PERSONNEL
At a minimum, ground fault circuit interrupter (GFCI) protection shall be provided for all 125-volt, single-phase, 15- and 20-ampere receptacles located outdoors; elevator electrical systems; as required by NEC Article 620, the *Safety Manual*, and the National Research Council's *Prudent Practices*; and receptacles installed on roofs. GFCI protection shall also be required in the following circumstances:

- In any location where EPA personnel are operating electrical equipment in direct contact with water or other liquids or where electrical receptacles are installed within 6 feet of a sink provided with a plumbed water supply or a drain, tub, or other water source.
- If GFCI protection is prescribed for electrical equipment by the equipment's manufacturer.
- If previous experience indicates a need for GFCI protection.

This protection shall be provided in new and existing construction by means of interrupter devices incorporated in receptacles or circuit breakers. These GFCI receptacles may be terminating type or feed-through type, whichever will satisfy the need. GFCI receptacles shall be color coded or shall otherwise indicate GFCI protection. Scheduled testing of the GFCI is required in accordance with the manufacturer's recommendations, but not less than semiannually. Upon completion of the initial installation, the electrical ground system shall be checked or verified for continuity with the conduit system, the equipment housing, and the final connection to the receptacle grounding stud. In aquatic laboratories and other required areas, not only will the GFCI-protective device be installed in the receptacle, but also the receptacles will be connected to the grounded system.

16.4.6.2.3 REMOVAL OF GFCI CIRCUITS
Existing circuits with GFCI protection shall remain unless persistent problems are encountered or unless renovations occur that would alter the use so that GFCI protection is not necessary. An example of such a renovation would be converting an aquatic laboratory to office space.

16.4.6.3 MOTOR CONTROL CENTER

Where several motors (all of larger-than-fractional horsepower) are located in one room or space, a motor control center should be used. Busing in the control center should be arranged so that the center can be expanded from both ends. Bus shall be of silver-plated copper. Interconnecting wires shall be copper.Terminal blocks should be of the plug-in type so that controllers may be removed without disconnecting individual control wiring.

16.4.7 GROUNDING

The grounding system must meet the requirements of the NFPA 70 and IEEE 142. All electrical outlets and non-current carrying metal parts of permanently connected electrical equipment shall be permanently connected to ground. All EPA facilities will be provided with two different equipment grounding systems: the general facility grounding system that is connected to the building structure and other systems, and an isolated grounding system to provide equipment grounding to the laboratory and critical computer equipment. Raceway systems shall not be accepted as the only grounding path. The isolated grounding conductors shall be green and the general facility ground conductor shall be gray.

16.4.7.1 LABORATORY BUILDING MODULE GROUNDING

All laboratory building modules shall be connected to the isolated grounding system described in paragraph 16.4.8. The isolated grounding system shall consist of a bare earth copper ground grid or field, direct buried outside to provide an isolated ground for instrumentation. This ground system (critical computer equipment in areas of the facility other than in the laboratory modules are also connected to this isolated grounding system) shall be clearly identified and protected against improper usage. All building ground systems shall be tied together as required by NEC Article 250.

16.4.7.2 GROUND BUS

Every panelboard and switchboard in the facility shall be provided with a ground bus.

16.4.8 LABORATORY POWER REQUIREMENTS

Specific and generic electrical requirements are indicated for most spaces in the room data sheets generated during the pre-design process. In the design of a new facility, however, these requirements must be reviewed, verified, and tested with the appropriate EPA representatives and must gain approval from EPA. This reviewing, verification, and testing should occur during the program verification and design phase of the project.

Duplex convenience outlets shall be laboratory standard grade, 20 amps, 120 volts in surface metal raceways, as defined below. These outlets should be provided in addition to specific electrical outlets and receptacles called for or shown in the respective room data sheets, and in addition to outlets needed to feed the equipment used in each room. These convenience outlets shall be located either on the reagent shelf or, if no reagent shelf is required, 8 inches above countertop level when base cabinets are used, and 44 inches above floor level in other locations. The maximum spacing between convenience outlets shall be 3 feet. In addition, the following requirements apply:

- Peninsulas. Provide a quadruplex receptacle outlet every 3 feet over the peninsula on overhead carriers (these carriers also support the various gas lines that terminate at the peninsulas). No pedestal receptacle outlets shall be installed. The receptacles on the overhead carriers shall be installed in surface metal raceway mounted to the overhead carriers.

- Equipment Outlet Location. Electrical outlet location shall be near the equipment to be powered; the exact location of equipment and outlets shall be determined by the Government during early design stage.

- All 120-volt general convenience receptacles shall be rated a minimum of 20 amperes and shall be grounding type (NEMA 5-20R) and specification grade.

- 120-volt circuits shall have a minimum rating of 20 amperes.

- A maximum of four general convenience receptacles shall be connected to a circuit.

- Equipment such as refrigerators, freezers, and centrifuges shall each have individual dedicated circuits.

- Receptacles located within 6 feet of a sink (or other water sources) shall be GFCI type.

- All branch circuits or panelboard feeder conduit runs shall be provided with separate equipment grounding conductors sized per NEC Table 250.122.

- Each laboratory shall be provided with separate, dedicated 120/208-volt, three-phase, four-wire panelboards; panelboards shall be spaced at a maximum spacing of one panelboard every two modules.

Additional panelboards shall be provided as required by electrical usage or as directed by the EPA project officer.

- Each laboratory panelboard shall be provided with a separate ground bus.

- Receptacles that are located above wall, peninsula, or island benches and at equipment spaces shall be in surface metal raceways wherever possible. Raceways shall be single compartment or double compartment (for both power and telecommunications/data) as directed by the EPA project officer.

- In accordance with NEMA 14-30R, 30-ampere, 125/250-volt single-phase receptacles will be provided for 30-ampere, 208-volt single-phase equipment.

- One receptacle on a dedicated 20-ampere, 120-volt emergency power circuit shall be provided in each laboratory. Emergency power shall also be provided for special equipment requiring such power.

- UPS systems within the computer/data-processing rooms and laboratories and their supply and output circuits shall comply with NEC Article 645.10. The disconnecting means shall also disconnect the battery from its load.

16.5 Interior Lighting System

16.5.1 ILLUMINANCE LEVELS

The minimum acceptable levels of maintained general overhead illuminance shall be as indicated in Table 16.5.1, Illuminance Levels, for the particular areas. The maximum illuminance level shall be no greater than 115% of the minimum level of the table. Illuminance levels shall manifest an energy conserving design that indicates coherence to EPA energy conserving initiatives. For areas not listed in Table 16.5.1, the recommendations of the Illuminating Engineering Society (IES) handbooks shall be followed. The lighting illuminance on the work surface or at the prescribed height above finished floor (AFF) is to be the area with the highest illuminance level within the lab module or office space.

Table 16.5.1 Illuminance Levels

FUNCTION	FOOTCANDLES	FUNCTION	FOOTCANDLES
General office space - ambient and task	50	Parking, driveway, and walkways	1-3
Animal room	70	Stairways	20
Autopsy	100	Storage	
Boiler room	20	Inactive	5
Corridors	10	Rough bulky	10
Emergency lighting (general, at floor level)	3	Medium	20
Emergency lighting in laboratory blocks, at floor level	5	Fine	50
Examination	100	Telephone equipment room	70
Laboratory module at work surface 36 inches AFF (dual switching)	50/100	Toilets	30
Loading dock	20	Exterior entrances	5
Lobby	20	Desk level (task lighting)	50-100
Locker rooms	20	Utility rooms	20
Shops (dual switching)	50/100	X-ray	10
General office and record rooms - ambient and task	50	Parking decks	5
		Library-conference rooms (dual switching)	50/100

Note: These values represent general illumination 30 inches above the floor unless indicated otherwise.

16.5.2 LIGHTING CONTROLS

Switches shall be provided to control lighting in all areas. Provide at least one switch for room lighting at 54 inches above the finished floor at each door that provides hallway egress and the controls described below. Large rooms (more than 200 square feet) shall have multiple switching to reduce the lighting level by approximately half.

16.5.2.1 DAYLIGHT-LEVEL SENSORY CONTROLS

In building areas (except laboratories) that are larger than 200 square feet and that will have a large contribution of natural daylight, daylight-level sensory controls shall be used to control lighting levels.

16.5.2.2 BUILDING AUTOMATION SYSTEMS

In buildings with building automation systems (BAS), the BAS (in addition to light switches) shall control overall building lighting. Each floor shall be a separate control zone with appropriate subzoning of each floor for special functions.

16.5.2.3 OCCUPANCY SENSORS

Occupancy sensors shall be provided (in addition to switches) to control lighting in offices and smaller rooms, bath and locker areas, conference rooms, storage rooms, and mechanical rooms. For offices, conference rooms and other non-support rooms, the occupancy sensors shall be manual on/automatic off type.

16.5.3 LAMPS AND BALLASTS

Electrical discharge lamps and high-intensity discharge (HID) lamps should be the primary lamps considered in the selection of the illumination concept. The lighting system shall use, to the maximum extent feasible, energy-efficient fixtures with electronic high-frequency ballasts, T-5 and T-8 fluorescent lamps, and high-quality light reflectors and lenses. The use of filament light sources should be kept to an absolute minimum (i.e., only in spaces that do not have a need for high levels of illuminance, that are normally occupied only for short durations, and for which discharge lamps are not suitable). Where fluorescent lamps will be utilized, these lamps shall be of the T-5 or T-8 type to conserve energy.

16.5.3.1 INDOOR HID LIGHTING

In using HID lighting indoors, the required color rendition shall be carefully considered from both visual and health safety perspectives.

16.5.3.2 BALLASTS

All ballasts to be used in EPA facilities shall be of the energy-saving type (electronic high-frequency ballasts shall be used in all possible locations).

16.5.3.3 LIGHT FIXTURE SELECTION

The selection of light fixtures should involve careful consideration of the quality of construction, ease of maintenance, ease of relamping, efficiency, illumination characteristics, mounting technique, and special purpose characteristics (e.g., vapor-proof, explosion-proof, elimination of radio frequency interferences). For office areas and laboratories, pendant lighting with direct/indirect light is recommended.

16.5.4 EMERGENCY LIGHTING (GENERATORS AND BATTERY UNITS)

An emergency lighting system shall be provided in accordance with NEC Article 700 and arranged to provide a minimum of 3 footcandles of illumination (measured at floor level) throughout the path of egress, including exit access routes, exit stairways, and other routes, such as exit passageways to the outside of the building. The emergency lighting system in laboratory modules shall provide a minimum of 5 footcandles of illumination.

- Laboratories and large open areas such as cafeterias; assembly areas; large mechanical, electrical, and storage rooms; and open-plan office spaces where exit access is normally through the major portion of the areas shall be provided with emergency lighting. In addition, emergency lighting systems shall be provided in computer rooms and in any location where chemicals are stored, handled, or used.

- The emergency lighting in laboratory rooms should provide at least 5 footcandles of illumination, measured at the exit access door.

- The type of system used shall be such that it will operate in the event of any failure of a public utility or internal disruption of the normal power distribution system in a building.

- Buildings seven stories high or less may be powered from two separate substations which are served by two different primary lines not constructed in the same right of way or path. This dual feeder arrangement can be used instead of having to install an emergency generator, but the transfer to feed the building from one substation to the other must be automatic and within the maximum time lapse required by the life safety code and the facility operation needs.

- Egress lighting in offices/lab areas should be connected to the fire alarm system, where permitted by code, so that these lights do not remain on 24 hours/day.

- The emergency lighting shall be connected to a generator, when a generator is provided. In buildings where there is no emergency generator, battery backup shall be provided for egress and emergency lighting. This battery backup may be by unit-type battery fixtures, battery packs in fluorescent fixtures, or use of inverters. Where HID lamps are used (and connected to a generator), a standby lighting system shall be provided to meet emergency lighting requirements during HID lamp restrike periods.

16.5.5 ENERGY CONSERVATION

EPA seeks to minimize energy use dedicated to electric lighting and the resulting cooling loads through proper use of natural lighting in the facility. In effect, it seeks a well-integrated lighting system for its new buildings that makes optimum use of both natural and artificial lighting sources and balances the buildings' heating and cooling needs. A lighting-power budget shall be determined, in conformance with ASHRAE 90, and strictly adhered to in the design of the lighting and cooling load for each facility. This budget may be exceeded in laboratory areas and in shops where a higher level of illumination is required because of the type of work being performed. All design of lighting for EPA facilities shall be in accordance with the EPA Energy Star Program.

16.5.6 GLARE

The selection of the type of diffuser and lens to be used on the lighting fixtures shall take into account the glare that can be produced on the work surface. All lighting design shall minimize the effects of glare on the task surface. Indirect lighting shall be used wherever possible. Additionally, fixtures should be located to keep glare to a minimum. In locating lighting fixtures, consideration must be given to the fact that many of the surfaces in the facility (especially in laboratory areas) have highly reflective materials at the task location.

16.5.7 AUTOMATIC DATA PROCESSING AREAS

Lighting fixture types, location, and illumination levels shall be coordinated with the equipment and functions of the telecommunications, alarm, and automatic data processing (ADP) centers to provide the required illumination without:

- Interfering with prompt identification of self-illuminated indicating devices
- Creating reflecting glare that might detract from adequate observations of essential equipment
- Creating electrical or electromagnetic interference detrimental to proper operation of equipment.

16.6 Fire Safety Requirements for Lighting Fixtures

Lighting fixtures shall comply with the NEC and the following criteria.

16.6.1 MOUNTING

All lamps shall be mounted in a way that prevents direct contact between the lamp and any combustible material. Wherever accidental contact is remotely possible, the lamp shall be protected by a guard, globe, reflector, fixture, or other protective means (NEC Article 410).

16.6.2 FLUORESCENT FIXTURES

All fluorescent fixtures installed indoors shall be provided with ballasts that have integral thermal overload protection (NEC Article 410).

16.6.3 LIGHT DIFFUSERS

Light diffusers shall be either of noncombustible material or of a design or material that will drop from the fixture before ignition. Where combustible dropout-type fixtures are used, plastic material shall not constitute more than 30 percent of the total ceiling area. Where luminous or diffuser ceilings are used, these restrictions also apply.

16.6.4 LOCATION

Lighting in locations where dangerous gases, liquids, dusts, or fibers may exist shall meet the requirements of NEC Article 500.

16.7 Exterior Lighting Systems

16.7.1 GENERAL

Exterior lighting systems shall comply with the IES Lighting Handbook. System controls shall use a time clock and/or photocell to provide illumination only when needed. In buildings with a building automation system (BAS), exterior lighting circuits shall be switched by photocells and the BSA system, which shall be able to override the photocell switch on request.

16.7.1.1 EXTERIOR LIGHT GLARE

Light glare shall be kept to a minimum in situations where it would impede effective operations of protective force personnel; interfere with rail, highway, or navigable water traffic; or be objectionable to occupants of adjacent properties. Uplighting should be minimized.

16.7.1.2 HIGH INTENSITY DISCHARGE LAMPS

Maximum use shall be made of HID lamps such as metal halide or high-pressure sodium vapor lamps.

16.7.2 PARKING LOT LIGHTING

Lighting over driveways and parking areas shall consist of a complete HID lighting system, including control equipment, underground wiring, luminaries, and all necessary accessories for a complete and functioning system. The maintained level of illumination shall be at least 1 to 3 footcandles. Consideration shall be given to reducing the amount of light in parking lot areas during times (e.g., between 12:00 AM to 4:30 AM) when it is very unlikely that the lots will be in use. EPA personnel at the site shall be contacted and approval must be obtained from the appropriate EPA facility personnel prior to incorporating this lighting feature into the design.

16.7.3 BUILDING EXTERIOR LIGHTING

Appropriate security and accent lighting shall be provided. All exterior doors and entrance ways shall be illuminated for security. Entrance ways shall have a maintained illumination level of at least 3 footcandles. Entrance ways with cameras shall have an illumination level as required by the security camera to operate.

16.7.4 TRAFFIC CONTROL LIGHTING

If the facility is on a site where traffic controls are necessary and will not be provided by the local municipality or state transportation authority, a complete traffic control system for the facility shall be designed, including all stoplights, directional lights, controls, and wiring, for a complete operating system.

16.7.5 ROADWAY LIGHTING

All new access roadways, or continuations of loop or access roadways, and driveways shall be lighted. The maintained level of illumination shall be at least 1 to 3 footcandles on vehicular roadways and pedestrian walkways. The same type of lighting that is used for parking lots (HID source) shall be used for roadways.

16.7.6 EXTERIOR ELECTRIC SIGNS

All exterior electric signs and nonelectric signs shall be integrated into the total design of the facility and approved by the Contracting Officer's Representative (COR).

16.8 Emergency Power System

16.8.1 GENERAL

An emergency power system shall be designed and provided for all administrative and laboratory space. The system shall provide electric power in the event of loss of normal power and shall provide power for emergency and egress lighting. The system shall also supply power to critical equipment during planned outages for maintenance. The emergency power system shall comply with NFPA 37, NFPA 70 (the NEC), NFPA 101, NFPA 110, and IEEE 446.

16.8.1.1 BATTERY-TYPE LIGHTING

In smaller buildings when the emergency power system is installed primarily for egress lighting, battery-type lighting units shall be used.

16.8.1.2 EMERGENCY POWER

In facilities where the emergency power needs are larger than can be handled by battery packs, an emergency power source shall be supplied. Normally, the emergency power source will be a generator; however, other power sources should be considered by the design professional whenever they appear to be feasible, can be justified for approval by EPA, are allowed by the applicable code(s) (e.g., NFPA 101 and NFPA 110), and are acceptable to the local authorities having jurisdiction. Alternate sources that might be considered, but not necessarily be limited to, fuel cells, micro turbines, turbines, photovoltaic (solar), wind, and biomass. The design professional shall justify the use of emergency power sources other a than generator by submission of design justification documents to EPA for approval. These justification documents shall include a complete life cycle cost analysis indicating a payback period acceptable to EPA, a narrative pertaining to the reliability of the current technology of the source, a narrative of the availability and applicability of the particular source to the specific facility and environment, a discussion of environmental impact considerations, and any other pertinent information relating to the alternative source that may be necessary for EPA to determine if the alternative source is acceptable for the specific project.

When it is not feasible to consider other sources for a specific project or when other sources prove to be unacceptable, a diesel engine-driven generator shall be provided to serve as the emergency source of power. If the loads and the availability of natural gas allow, a natural gas generator shall be considered. Any emergency power system provided shall be equipped with phase-synchronized automatic transfer switch or switches and with necessary controls for automatic operation. All automatic transfer switches shall be of the isolation/bypass type. The generator(s) (or alternate emergency power source) shall transfer and pick up the critical load(s) within 10 seconds. The system shall be able to carry a continuous full load for not less than 24 hours. The generator exhaust and fuel pipe vents shall be arranged and located away from fresh-air intakes. The generator exhaust shall be located where maximum dilution can be accomplished. The generator shall be water cooled. The emergency power source shall be designed to handle nonlinear loads.

16.8.1.2.1 EMERGENCY POWER REQUIREMENTS

Table 16.8.1, Emergency Power Requirements, outlines the emergency power requirements for different building heights and particular fire safety systems. Generators are not required by these criteria unless an analysis of the cost of installation and maintenance of acceptable emergency power sources shows that a generator is the most cost-effective power source or as required by applicable codes and authorities having jurisdiction (however, a generator may be required by EPA regardless of the outcome of this analysis). Automatic switching schemes shall be provided for all emergency power sources. Where emergency generators are used, their installation shall be in accordance with NFPA 110 and NEC Article 700.

Table 16.8.1 Emergency Power Requirements

	Acceptable Sources of Emergency Power*	
Emergency System	**Building Height † 75 Feet or Less**	**Building Height † Over 75 Feet**
Emergency lighting (1½ hours)	1, 2, 3	1, 3
Exit lighting (1½ hours)	1, 2, 3	1, 3
Fire alarm	1, 3	1, 3
Fire pump	N.R.	1, 2
Jockey pump	N.R.	1, 2
Elevator	N.R.	1, 2*
Smoke control	—	N.R.
Sprinkler system air compressor	N.R.	N.R.
Special extinguishing system power supply (dry chemical, CO_2, or other EPA-approved system)	N.R.	N.R.
Fume hoods (full or partial containment or where deemed necessary)	1, 2	1, 2

Note: 1 = Generator; 2 = Connection either to two separate primary sources or to a utility network system; 3 = Battery with charger; N.R. = Not Required.

* Power source must be capable of providing power to one elevator on a selective basis when the building contains six or fewer elevators. Otherwise, two elevators must be supplied on a selective basis.

† The building height for application of the criteria shall be determined by measurement of the distance from grade level of the lowest accessible floor to ceiling height of the highest occupied floor in the building. Mechanical rooms and penthouse are not considered occupied floors in this case.

16.8.1.3 EMERGENCY GENERATOR LOCATION

The preferable location for the generator is outdoors. However, whatever the final approved location of the generator might be, the design professional must adhere to the following location parameters: locate with exhaust away from fresh air intakes; and locate away from vibration, acoustic, or electrically sensitive equipment. The location should be such that the generator will be hidden from view (including screening, as necessary, to appropriately hide the generator) and should be to the rear of the main facility when located outdoors (the preferred location). The generator should be placed over vibration isolators and should make use of noise dampers and other devices, as required, to substantially attenuate noise and vibration resulting from its operation. The generator exhaust requirements must be addressed and incorporated into the design. The generator shall be equipped with a low-noise exhaust silencer (hospital or critical type) and weatherproof housing (outdoor locations). If the generator is located indoors, the size and shape of the generator room, including usable space around the generator, must be considered and resolved during the facility design phase. Additionally, fuel supply and location (incorporating code and environmental requirements) must also be addressed during the design phase.

16.8.1.4 ECONOMIC ANALYSIS

For all installations where a generator is provided, an economic analysis shall be done to determine the economic feasibility of including load-shedding or peak-shaving equipment as part of the installation. EPA will provide instructions on the possible inclusion of this item in the project after the economic analysis has been completed. It shall be the responsibility of the design professional to specifically request these instructions pertaining to the inclusion of this item from EPA after completion of the economic analysis.

16.8.1.5 FUEL STORAGE TANK

If a diesel-type generator is used, the system shall be provided with a fuel storage tank that is capable of carrying a continuous full load for not less than 24 hours. The preferred type of tank is an aboveground storage tank. If allowed by EPA, the tank may be installed underground. If so, the tank shall be of double-wall construction and of noncorrosive material with interstitial monitoring capabilities. The tank shall meet the most current promulgated rules effective on the date of installation. The design professional shall justify in writing the need or lack of need, whichever may be the case, for a cathodic protection system for the site and type of construction and equipment specified. This evaluation shall be submitted with the first submission.

16.8.2 EMERGENCY LOADS

In addition to the loads required by NFPA 101, NEC, and the room data sheets, the following loads shall be connected to the emergency power system:

- Fire alarm system
- Exit lights
- Emergency lighting system—3 footcandles minimum for egress; 10 footcandles at switchboards
- Critical operations laboratory equipment
- Telephone relay system
- Certain HVAC systems (as required by the applicable state and local codes and as directed by EPA)
- Critical sump pumps and other associated mechanical equipment and controls
- All animal care facilities
- Local HVAC air compressors for special rooms
- Paging system
- Selected elevators (as required by the applicable state and local codes and as directed by EPA)
- Gas chromatograph
- Selected refrigerators and freezers (as directed by EPA)
- Incubators
- X-ray fluorescent analyzer
- UPS system
- Air-conditioning system associated with computer rooms, UPS room, and environmental rooms
- Security systems
- Safety alarm systems.

16.8.3 UNINTERRUPTIBLE POWER SUPPLY

A UPS system shall be provided for loads requiring guaranteed continuous power. The application of UPS systems shall comply with IEEE 446. The design professional shall make a recommendation concerning the appropriate type of system for a particular facility (i.e., rotary or stationary [static] type). UPS equipment shall be capable of supplying power through multiple means (normal, static switch bypass, and total system bypass). The UPS system shall be sized to provide at least 5 minutes of protection upon loss of normal power. The UPS system shall be rated for “multi-range” input voltage and shall provide a sinusoidal or, as a minimum, a quasi-sinusoidal power output wave form. Total system bypass power shall include an isolation transformer. All components shall be UL listed. The supplied UPS system shall be specified to operate properly with an emergency generator.

16.8.3.1 MINIMUM REQUIREMENTS

The UPS system shall operate continuously and in conjunction with the existing building electrical system to provide precise power for critical equipment loads. The static system shall consist of a solid-state inverter, a rectifier/battery charger, a storage battery, a static bypass transfer switch, synchronizing circuitry, and an internal maintenance bypass switch. The rotary system shall include a solid-state inverter, a battery charger, a storage battery, an automatic transfer assembly, an internal (automatic) bypass switch, and a low-voltage transient synchronous generator with flywheel. The UPS system, along with the supporting equipment, shall be housed in dedicated room(s) under controlled environmental conditions that meet the manufacturer's recommendations and code requirements.

16.8.3.2 CODES, STANDARDS, AND DOCUMENTS

The UPS shall be designed in accordance with the applicable codes and standards of the following:

- NFPA
- NEMA
- IEEE inverter standards
- ASA
- American Society of Mechanical Engineers (ASME)
- National Electrical Code (NEC)
- Occupational Safety and Health Administration (OSHA)
- Local codes.

16.8.3.3 ON-LINE REVERSE TRANSFER SYSTEM

The UPS shall be designed to operate as an on-line-reverse transfer system in the following modes:

- Normal (Static). The critical load shall be continuously supplied by the inverter. The rectifier/battery charger shall derive power from the utility alternating current (AC) source and it shall in turn supply direct current (DC) power to the inverter while simultaneously float-charging the battery.

- Normal (Rotary). The critical load shall receive power from the motor-generator set which is supplied power from the utility company. While the motor-generator supplies power to the critical load, it simultaneously charges the batteries.

- Emergency (Static). Upon failure of the utility AC power source, the critical load shall be supplied by the inverter, which, without any switching, obtains its power from the storage battery. There shall be no interruption to the critical load upon failure or restoration of the utility AC source.

- Emergency (Rotary). Upon failure of the utility AC power source, the control logic shall turn on the inverter which is supplied power from the battery. The inverter then supplies AC power to the motor-generator set which subsequently supplies power to the critical load. The inverter shall be capable of full-power operation within 50 milliseconds after loss of utility power.

- Recharge. Upon restoration of the utility AC source (prior to complete discharge of the battery), the rectifier/battery charger powers the inverter and simultaneously recharges the battery. This shall be an automatic function and shall cause no interruption to the critical load.

- Bypass mode. If the UPS must be taken out of service for maintenance or repair of internal failures, the static bypass transfer switch shall be used to transfer the load to the utility alternating current (AC) source without interruption. Automatic transfer of the load shall be accomplished after the UPS inverter output synchronizes to the utility alternating current (AC) source (or the bypass input source). Once the sources are synchronized, the static bypass transfer switch shall transfer the load from the bypass input source to the UPS inverter output by paralleling the two sources and then disconnecting the bypass AC input source. Overlap shall be limited to one-half cycle.

- Maintenance bypass/test. Test switching shall be provided to simulate a normal power outage, transfer the load to the source of backup power through the UPS, and switch the load back to the normal power source upon completion of the test.

- Downgrade. If only the battery will be taken out of service for maintenance, it shall be disconnected from the rectifier/battery charger and inverter by means of an external battery disconnect. The UPS shall continue to function as specified herein, except for power outage protection and transient characteristics.

16.8.3.4 UPS OUTPUT

The UPS output shall have the following characteristics:

- Frequency: 60 hertz (Hz) nominal +0.5 Hz (when synchronized to the bypass AC input source).

- Output voltage transient characteristics for:

  - 25 percent voltage fluctuation load step change ±4 percent
  - 50 percent voltage fluctuation load step change ±6 percent
  - 100 percent voltage fluctuation load step change +10 percent/-8 percent.

- Output voltage transient response: The system output voltage shall return to within +1 percent of the steady state value within 30 milliseconds.

- Output voltage regulation: The steady state output voltage shall not deviate by more than +1.0 percent from no load to full load.

16.8.3.5 OUTPUT FREQUENCY REGULATION

The UPS shall be capable of providing the nominal output frequency ±0.1 percent when the UPS inverter is not synchronized (free running) to the AC bypass input line and also when the utility alternating current (AC) source is not available (i.e., operation from battery source only).

16.8.3.6 SYSTEM OVERLOAD

System overload is a load of at least 125 percent of the system rating for a period of 10 minutes, and 150 percent current for 1 minute. Overloads in excess of 170 percent of the UPS rating, on an instantaneous basis, or in excess of the overload time periods previously stated shall cause the static bypass transfer switch to reverse-transfer and allow the AC bypass input source to supply the necessary fault-clearing current. After approximately 5 seconds, the static bypass transfer switch shall automatically forward-transfer, and normal UPS operation shall resume. If the overload still exists after the 5-second period, the static bypass transfer switch shall automatically reverse-transfer the load to the AC bypass input source and the UPS inverter shall turn off. The system shall require manual restart after this sequence.

16.8.3.7 SYSTEM EFFICIENCY

The overall efficiency, input to output, shall be at least 95 percent with the battery fully charged and the inverter supplying full-rated load.

16.8.3.8 LOCATIONS AND LOADS

The UPS system shall be located in special rooms or in the same room as computer equipment. These rooms shall have special HVAC equipment to maintain the proper environmental conditions for the UPS system and its batteries both under normal conditions and during a power outage.

16.8.3.8.1 UPS LOAD

The UPS load will consist of the equipment and outlets designated for UPS power connection in the room data sheets.

16.8.3.8.2 BATTERY ROOM

The battery room for the UPS shall be well ventilated so as not to allow an explosive mixture of hydrogen to accumulate. Refer to Section 15, Mechanical Requirements, of this manual for the following battery room requirements: minimum air change rate, make-up air, monitoring, ventilation, emergency eyewash station, emergency shower, and all other mechanical requirements for this room. Additionally, these battery rooms shall contain all devices required by the *Safety Manual* (including mechanical ventilation, an emergency eyewash station, and a fire/smoke sensing device). The ventilation fans shall be connected to the emergency power system so that in the event of normal (utility) power system failure, electrical power to the fans will be maintained. The installation of the UPS system shall be in accordance with NFPA 111. Explosion-proof wiring methods, however, are normally not required in battery rooms. The provision for sufficient diffusion and ventilation of the gases from the battery to prevent the accumulation of an explosive mixture, as required by this paragraph and Section 15 of this manual, is necessary in order to prevent classification of the battery room as a hazardous (classified) location, in accordance with NEC Article 500. A fire- or smoke-sensing device shall be installed in battery rooms. Selection of this device should be appropriate to the design of the battery room.

16.9 Lightning Protection System

16.9.1 MINIMUM SCOPE

A lightning protection system shall be provided for all facilities containing laboratory modules, as well as for facilities containing radioactive or explosive materials. The requirements and installation criteria for lightning protection systems shall be in accordance with NFPA 780, UL 96A, and the local building code.

16.9.2 ADDITIONAL SCOPE

For building types not in the above description, the guide in NFPA 780 shall be used to assess the risk of loss due to lightning.

16.9.3 MASTER LABEL

For buildings described in subsection 16.9.1 and for facilities with a strong risk potential (per NFPA 780), equipment, accessories, and material necessary for a complete master-labeled lightning protection system for all building components should be furnished and installed. The system shall comply with NFPA 780, UL 96A, and Lightning Protection Institute (LPI) 175. All cables, lightning rods, and accessories shall be copper. All connections and splices shall be of the exothermic weld type.

16.9.3.1 MINIMUM REQUIREMENTS

The installed system shall be unobtrusive, with conductors built during construction (so they are concealed). The system shall also be properly flashed and watertight. Installation shall be done in conformance with shop drawings prepared by the supplier and approved by the EPA.

16.9.3.2 CERTIFICATION DELIVERY

Before the lightning protection system is accepted, the contractor shall obtain and deliver to the supervising architect the UL master label or an equivalent certification.

16.10 Seismic Requirements

16.10.1 SEISMIC REVIEW

The design and construction of all new EPA facilities shall comply with those standards and practices that are substantially equivalent to, or exceed, the *National Earthquake Hazard Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*.

16.11 Automatic Data Processing (ADP) Power Systems

16.11.1 COMPUTER POWER

All ADP equipment in a centralized ADP room shall be connected to the uninterruptible power supply (UPS) power. Utility or emergency input power to the UPS system shall be 480 Volt, 3 phase. Output power from the UPS system shall be 208Y/120 Volts. Power distribution units (PDUs) shall have 208Y/120 volt input and output power. UPS and PDUs shall have monitoring capabilities with transient protection. PDU shall limit the cable runs to 100 feet from the PDU to the ADP equipment. The user will provide a list of equipment cable types and plug types. All circuits shall have separate neutrals. All UPS units and PDUs shall be connected to a central monitoring and control system.

16.11.2 NON-UPS/PDU OUTLETS

Non-UPS/PDU outlets shall be spaced every 20 feet around the computer room for utility use (vacuums, drills, etc.).

16.11.3 LIGHTING

Under-floor lights with cutoff timer(s) shall be installed in computer room(s). Room lighting for computer rooms shall be either indirect lighting, to reduce glare on terminal screens, or overhead lighting of the parabolic type, to reduce eye strain.

16.11.4 GROUNDING

All computer power shall be grounded to the isolated grounding system described in paragraph 16.4.8 of this section. This isolated grounding system can only be connected to the general facility power grounding system at the main building service entrance grounding electrode or at the isolation transformer/equipment grounding on a separately derived system. A grounding mat may be locally provided to the computer room to connect the non current carrying metal parts of the critical equipment, but this mat must be electrically isolated from the general facility grounding system in order to meet the NEC.

16.12 Cathodic Protection

16.12.1 GENERAL REQUIREMENTS

An investigation shall be conducted and a determination made, on whether cathodic protection is required for buried utilities. The design professional shall justify in writing the need or lack of need, whichever may be the case, of a cathodic protection system for the type of construction and equipment specified for each specific buried utility. This evaluation shall be submitted with the first submission. For additional information on corrosion control requirements for underground fuel storage tanks, see paragraph entitled "Fuel Storage Tank" of this section. If a cathodic protection system is required, a system shall be recommended to satisfy the local conditions. The cathodic protection system shall be designed by a professional who is certified by NACE International as a Cathodic Protection Specialist or Corrosion Specialist or who is a registered professional corrosion engineer. Additionally, the design professional must have a minimum of 3 years experience in similar installations. The cathodic protection design, as a minimum, shall be in compliance with the applicable NACE International standard corresponding with the type of structure that is to be cathodically protected. The installed cathodic protection system shall be able to provide protective currents to the intended structure meeting the minimum performance criteria as defined in NACE International standards.

16.13 Environmental Considerations (Raceways, Enclosures)

16.13.1 CORROSIVE ATMOSPHERE

Special consideration shall be given to the type of raceways to be used in corrosive environments (such as chemical storage areas, some laboratories, and areas near air exhausts for spaces with corrosive fumes). All raceways to be used in corrosive atmospheres shall be deemed suitable by the raceway manufacturer for the atmosphere in which they will be installed.

16.13.1.1 EQUIPMENT ENCLOSURES

The enclosures for electrical equipment (e.g., panels, switches, breakers) shall have the proper NEMA rating for the atmosphere in which the equipment is being installed.

16.13.2 SALTWATER ATMOSPHERE

Only hot-dipped galvanized steel and PVC conduit and fittings are acceptable for buildings in salty weather areas.

16.13.3 EXTREME COLD

Electrical equipment such as emergency generators, transformers, and switch gear installed in weatherproof enclosures of the facility that are subject to extremely cold temperatures should be provided with supplemental heating within the enclosures.

16.14 Communication Systems

16.14.1 TELECOMMUNICATIONS/DATA SYSTEMS

One telephone outlet and one Local Area Network (LAN) computer shall be provided per 125 net usable square feet (NUSF) of office space. If workstations are identified and are smaller than 125 NUSF, one telephone outlet and one LAN outlet will be required per workstation or single module space. One telephone outlet and one Laboratory Information Management Systems (LIMS) shall be provided per single laboratory module space. One LIMS outlet shall be provided per 125 NUSF of laboratory office space. The exact location for all communications/data outlets shall be determined by the Government at an early design stage. All telephone and computer outlets shall be provided with PVC or equivalent corrosion-resistant cover/face plates; metal covers shall not be used.

16.14.2 VIDEO CONFERENCE ROOMS

Cabled video teleconference space (CVTS) communication wiring should be limited to 300 unrepeated cable runs. The network interface (service delivery point) to support CVTS rooms will be located in the network control facility (NCF); therefore, CVTS room locations must be within 300 cable feet of the NCF and have conduit access for 22-gauge shielded solid copper twisted-pair wire. Longer runs may require repeaters and require additional expenses, but they must remain within the 1.5-decibel loss specifications of the technical advisory manuscript concerning the wiring.

16.14.3 RECORDING SYSTEMS

In areas where conferences are to be recorded, built-in microphones shall be provided along with a closet containing the recording equipment. Wiring shall be installed from the microphone (omnidirectional) to recorders for a complete system.

16.14.4 SATELLITE DISHES

An area may be required for the installation of satellite dishes that will be used for telecommunications, television reception, or data transmission. If required, an area shall also be designed for location of satellite dish head-in equipment (receivers and transmitters). Where use of a satellite dish is required, power shall be furnished for all head-in equipment. Cable raceways shall be provided from the satellite dish location to the room for the head-in equipment and from the head-in equipment to each outlet served and to the controller location for the dish. All equipment and cable will be furnished by EPA.

16.14.5 TELEVISION BROADCAST SYSTEMS

In facilities from which a local or national television station will be broadcasting live meetings or press conferences, a complete raceway (or cable-tray) system shall be furnished to allow the station to run cables from the designated television van parking areas to the conference/press room. If cable tray is provided, it shall be completely accessible throughout its length.

16.14.5.1 WEATHERPROOF RECEPTACLES/DISCONNECT SWITCHES

In addition, weatherproof receptacles or disconnect switches (fused) shall be provided at the van parking areas to allow each van to receive power from the building.

16.14.6 MICROWAVE COMMUNICATIONS

Where required, an area shall be designed for the installation of a microwave dish that will be used for telecommunications or data transmission. An area shall also be designed for microwave head-in equipment. Power shall be furnished for all head-in equipment. Cable raceways shall be provided from the microwave dish location to the room for the head-in equipment and, from there, to the room where the controller will be located. All equipment and cables will be furnished by EPA.

16.14.7 OTHER

A complete raceway system shall be furnished for other communication/data systems (systems not otherwise mentioned in subsection 16.14). The raceway system shall include raceways, outlet and junction boxes, and power connections (direct or receptacle) for all associated equipment to be located in the facility. Unless otherwise directed by EPA, all cabling and equipment for these other systems will be furnished by EPA.

16.15 Alarm and Security Systems

16.15.1 FIRE ALARM SYSTEM

Fire alarm systems must be installed in accordance with NEC Article 760 and NFPA 72. Devices that activate fire alarm systems and evacuation alarms must be completely separated from other building systems such as environmental monitoring systems and security systems. Other features of the fire alarm system (e.g., fan shutdown) may be shared with these other building systems, but the performance of the fire alarm system must not be compromised and must meet the requirements stated in this subsection. In general, auxiliary functions, such as elevator recall and smoke control, are not performed by the fire alarm system but by other mechanical or electrical systems. The main fire alarm system should supervise any auxiliary system (e.g., computer room). Activation of the main fire alarm shall also activate the audible (and visual, if applicable) devices of the auxiliary system in the associated alarm area. The fire protection system shall be in compliance with the most current codes and publications, as listed below (see other sections for additional codes and standards):

- Sprinkler Systems, NFPA 13
- Standpipe and Hose Systems, NFPA 14
- National Electrical Code, NFPA 70
- National Fire Alarm Code, NFPA 72
- Installation of Air Conditioning and Ventilating Systems, NFPA 90A
- Life Safety Code, NFPA 101
- GSA handbook PBS-P100, Facilities Standards for the Public Building Service
- UFAS and ADA Requirements
- *Safety Manual*, Chapter 2
- Local codes.

16.15.1.1 GENERAL SYSTEM REQUIREMENTS

Pull stations shall be installed adjacent to all exit doors and all exit stairs' access doors. Automatic smoke and temperature rise detectors shall be installed as required by all applicable national and local codes and as determined by the standard practice. Activation of a manual station or any of the automatic detectors shall set off the fire alarm system throughout the building or the building zone, and shall send an alarm signal to the local fire department or a central station service unit. Activation of any automatic fire suppression system (sprinkler or chemical) shall set off the fire alarm as described for a manual station but will also send a suppression activated signal to the local fire department or a central station service unit, as required. The fire alarm system shall be totally supervised. All alarm initiating devices, all the alarm conditions indicating devices, all fire alarm signal carrying circuits, the fire alarm back up battery system, the circuits carrying the fire alarm signal to the local fire station or to a central station service unit, all the sprinkler system and/or standpipe system valves and switches operational position shall be supervised. The supervisory system alert signal shall be different than a fire alarm signal and shall be transmitted both to the local fire station or central station service unit and to the building's fire alarm control panel. The buildings shall be divided into fire zones and the elevator lobbies smoke detection system shall have its own zones with its own identifiable codes or labeling system. Activation of any smoke detector shall send a pre-alarm conditions signal to the local fire station or central station service unit and to the building's fire alarm control panel.

16.15.1.2 BASIC REQUIREMENTS

Unless the most recent edition of NFPA 101 has more stringent requirements, fire alarm systems are required, as a minimum, in any office, computer room, library, classroom, meeting room, cafeteria, or similar business-type occupancy, if the occupancies have any of these characteristics:

- The occupancies are two or more stories above the level of exit discharge.
- The occupancies may have 100 or more occupants, above or below grade.
- The occupancies consist of more than 50,000 square feet.
- A human voice, gas-powered horn, or other similar nonelectric system cannot efficiently or effectively be used to alert occupants to an emergency.

Storage occupancies equal to or larger than 100,000 square feet shall have fire alarm systems. All other occupancies shall follow the requirements in NFPA 101.

16.15.1.3 MANUAL SYSTEMS INPUT

Each system shall provide manual input from manual fire alarm stations, which shall be located in exit or public corridors adjacent to each stairway and to each exit from the building. Additional stations may be provided at any location where there is a special risk or where the travel distance to the nearest station exceeds 200 feet. As a general principle, the station shall be placed so that a person using it will be between the fire and the exit. If necessary, emergency telephone systems shall be provided in the exit stairs or in another protected location, as indicated for manual fire alarm stations. In addition, telephones shall be provided at each elevator lobby, at the ground floor, and on alternate elevator-capture floors.

16.15.1.4 AUTOMATIC SYSTEMS INPUT

Automatic fire detection shall be provided as described below.

- A water flow switch shall be provided for each floor or fire area protected by wet-pipe sprinkler systems. Other types of sprinkler systems will be activated by a pressure switch at the dry or deluge valve only.

- Automatic heat or smoke detection shall not be installed in lieu of automatic sprinkler protection unless this decision is otherwise supported through recognized equivalency methodologies (NFPA 101A). Detection shall be provided where a preaction or deluge sprinkler system exists. Automatic sprinkler protection requirements are described in Section 13, Special Construction, of this Manual.

- In accordance with NFPA 72, smoke detectors shall be provided for essential electronic equipment, air-handling systems, and elevator lobbies and machine rooms. All smoke detectors shall be approved for their intended use and installation. Smoke detectors require periodic maintenance, and arrangements for this should be made at the time of installation to ensure proper operation and to guard against false alarm or unintended discharge.

- Heat and smoke detection in air-handling systems shall comply with NFPA 90A. Detectors, when required, shall be located in the main supply duct downstream of a fan filter and in the return air ducts for each floor or fire area.

- When heat and smoke detectors are installed, they shall be designed and installed in accordance with NFPA 72.

- Special hazard protection systems shall initiate an alarm. These special systems include, but are not limited to, dry chemical extinguishing systems, elevator recall systems, and computer detection systems.

- Supervisory signals shall be transmitted under each of the following conditions:

  - Operation of generator
  - Operation of fire pump
  - Loss of primary power to a fire alarm system, fire pump, or extinguishing system
  - Failure of any of the alarm initiating devices or circuits (open, grounding, etc.)
  - Failure of any of the alarm conditions indicating devices or their circuits (open, short, grounded, etc.)
  - Malfunctioning of the fire protection system battery back-up system
  - Failure of any of the signal circuits to equipment that respond to alarm initiating devices (e.g., signal circuits to elevators, to automatic fire doors, to smoke dampers, to automatic valves of dry sprinkler systems)
  - Failure of one of the circuits/channels that carries the fire alarm signal to the remote, constantly manned Central Fire Station
  - Loss of air pressure for dry-pipe sprinkler system
  - Loss of a central processing unit (CPU) or of CPU peripheral equipment in a multiplex system
  - Low water level in pressure tanks, elevated tanks, or reservoirs

- When control valves in the supply or distribution lines of automatic sprinkler systems, fire pumps, standpipe systems, or interior building fire main systems are closed either a maximum of two complete turns of a valve wheel or 10 percent closure of the valve, whichever is less. (In this case, the signal will be transmitted by tamper switches.)

16.15.1.5 AUTOMATIC SYSTEMS OUTPUT

The signal to all alarm condition indicating devices, the Central Fire Station, and all equipment, fire doors, etc., that respond to a fire alarm shall be transmitted automatically once a fire alarm station or a detector is activated. In no case shall these alarms depend on manual action. Various outputs include those listed below.

- Elevator control smoke detector actuation shall sound an alarm at the fire alarm panel, recall elevators, and notify the fire department but shall not initiate an audible alarm signal to building occupants or start any smoke control system, except as noted below. The smoke detector alarm signal shall be received at a central station or some other location that is constantly attended. This will ensure an investigative response to the alarm.

- General area smoke detectors shall initiate an evacuation alarm for the portion of the building or area in which they are used to increase the level of protection. In such situations, smoke detectors and fire alarm panels equipped to provide alarm verification may be desirable.

- All alarm signals or messages shall be continuous. Where public address systems are provided for the facility, there shall be provisions for making announcements from the main fire alarm panel or from an attended location where the fire alarm signal is received. The public address system does not have to be an integral part of the fire alarm system. Coded alarm signals are unacceptable.

- The output of special extinguishing systems, such as those provided for kitchens, shall include the actuation of the building fire alarm system. Special detection systems shall indicate a supervisory signal at the fire alarm panel.

- If an entire building can be evacuated within 5 minutes, the fire alarm shall sound either throughout the building or on selected floors. Where selective evacuation is used on the basis of local code requirements, features such as smoke control and automatic sprinklers shall be provided, as necessary, to ensure the safety of occupants remaining in the building.

- For voice communications systems, only the occupants of the fire floor, the floor below, and the floor above are expected to relocate or evacuate. These occupants must automatically receive that message and be notified of the emergency. Where automatic prerecorded voices are used, message arrangement and content shall be designed to fit the needs of the individual building (e.g., bilingual messages where appropriate).

- The use of visual signals to supplement the audible fire alarm system shall be provided in accordance with NFPA 72 and Title III standards of ADA and UFAS, as applicable.

- Every alarm reported on a building fire alarm system shall automatically actuate one of the following:

    - A transmitter listed by UL, connected to a privately operated, central-station, protective signaling system conforming to NFPA 72. The central-station facility shall be listed by UL; automatic telephone dialers shall not be used.

- An auxiliary tripping device connected to a municipal fire alarm box to notify the local fire department, in accordance with NFPA 72.

- A direct supervised circuit between a building and the local fire alarm headquarters or a constantly manned fire station, in accordance with NFPA 72.

- As a last resort, an alternate method approved by SHEMD.

• Notification of the fire department shall occur no more than 90 seconds after the initiation of an alarm. The specific location of the alarm may be determined by fire department personnel after they arrive.

• A supervisory condition shall transmit a separate signal to a central station, different from an alarm signal. No more than one supervisory signal shall be provided for an entire building. Refer to the automatic systems input information in subsection 16.15.1.3 above for required supervisory conditions.

• Additional automatic actions shall be performed for smoke control, elevator capture, and door closings. Smoke control and elevator capture shall be coordinated with the evacuation plan for a building. (A summary of system actions is shown in Table 16.15.1.)

Table 16.15.1 Status Condition

Output Function	Input Device					
	A	B	C	D	E	F
Transmit signal to fire department	X	X	X	X	X	
Indicate location of device on control panel and annunciator	X	X	X	X	X	X
Cause audible signal at control panel	X	X	X	X	X	X
Initiate emergency operation of elevators	X	X*		X		
Initiate smoke control sequence	X			X		
Result in a record on system printer	X	X	X	X	X	
Cause audible alarm signal throughout building (voice or nonvoice)	X			X		

A = Manual fire alarm station
B = Smoke detectors (other than duct)
C = Duct smoke detectors
D = Water flow detectors and automatic extinguishing systems
E = Supervisory device
F = Emergency telephone

Note: Only smoke detectors associated with the elevators (e.g., the elevator lobby) must initiate elevator emergency operation.

16.15.1.6 MANUAL SYSTEMS OUTPUT

Any action that can be performed automatically must be able to be initiated manually from the control center or fire alarm system control panel. A smoke control panel shall be provided when smoke control systems are required. The control center, or fire alarm system control panel, shall have the capability of canceling and restoring any action that has been initiated automatically or manually.

16.15.1.7 SYSTEMS FEATURES

All systems shall include the following:

• Indication of normal or abnormal conditions

- Annunciation of alarm, supervisory, or trouble conditions by zone
- Graphic annunciation of alarm conditions by zone
- Ringback feature when a silence switch for audible trouble signal is provided.

16.15.1.8 HIGH-RISE SYSTEMS FEATURES

For buildings 12 stories tall or higher, the systems shall also include the following:

- Permanent record of alarm, supervisory, or trouble conditions via printer
- Initiation of an alert tone followed by a digitized voice message.

All power supply equipment and wiring shall be installed in accordance with the requirements of NFPA 70 (NEC) and NFPA 72.

16.15.1.9 RELIABILITY

The maximum elapsed time from the moment that an alarm is activated to the moment that all alarm condition indicating devices and all alarm responding equipment are in operation shall not exceed 10 seconds. In accordance with and as defined in NFPA 72, the design professional shall indicate by class and style, the initiating device, notification appliance, and signaling line circuits, which shall define the circuit's capability to continue to operate during specified fault conditions. As a minimum, the system shall be designed such that any system alarm input device shall be capable of initiating an alarm during a single break, or a single ground fault condition, on any system alarm-initiating circuit. In addition, any signaling line circuit of a multiplex system (other than combination multiplex-point wired systems) shall also perform its intended service during a wire-to-wire short or a combination of a single break and a single ground of a circuit. The system shall also be designed requiring the provision of a looped conduit system such that if the conduit and all conductors within are severed at any point, all indicating device circuits (IDC), notification appliance circuits (NAC) and signal line circuits (SLC) will remain functional.

16.15.1.10 CODE COMPLIANCE, MANUAL SYSTEM

A complete, code-complying fire alarm system shall be designed. For small buildings, and where allowed by code, the system may be a manual system only. The manual system shall include manual stations, fire alarm annunciator signals, and an annunciator panel indicating the zone where the alarm was initiated. The alarm shall be sent to the local fire station.

16.15.1.11 CODE COMPLIANCE, AUTOMATIC SYSTEM

In large facilities, or where required by code, the systems shall be automatic and shall include smoke detectors, manual pull stations, rate of rise detectors, alarm bells or horns and strobe lights, sprinklers, and a central annunciator panel. Suppression systems shall be tied to the central annunciator panel. The fire alarm system shall be tied to the local fire station in the area. Smoke detectors shall be provided in all corridors and designated laboratory modules.

16.15.1.12 CENTRAL, LOCAL, AND PROPRIETARY ALARM SYSTEM

The building(s) shall be protected by a central, local, proprietary-type fire alarm system. Location of pull stations, bells, automatic fire detectors, and other equipment pertinent to the fire alarm system shall be in accordance with the referenced NFPA and local codes. When there is a difference between the NFPA codes and local codes, compliance with the most stringent code will be required. Visual alarms are required throughout the facility for handicapped fire warning.

16.15.1.13 CENTRAL STATION SERVICE

The building(s) shall be protected by a local fire alarm system(s) connected to either a UL-listed fire department station or a central station service unit meeting the requirements of NFPA 72.

16.15.1.14 FIRE ZONES

Building(s) shall be subdivided into fire zones as recommended by NFPA and state codes. Graphic annunciators shall be provided at the main entrances and the security control center. These annunciators shall clearly show the outline of the buildings, the fire zones, and the alarm-initiating devices. All signal devices shall be addressable (i.e., each device shall have its own address, which shall report to monitoring devices in the English language for clear and quick identification of the alarm source).

16.15.1.15 WIRE CLASS AND CIRCUIT SURVIVABILITY

The fire alarm system–initiating device circuits shall be wired Class A, Style 7, and alarm-indicating circuits (visual and audible) shall be wired Class A (NFPA 72).

16.15.1.16 CONTROL CENTER

Building(s) must have a control center where fire-related control panels are located. This control center must be located next to the main entrance and shall be separated from the rest of the building by 1-hour fire resistive construction. Emergency power, room illumination, room HVAC, telephone, and fire protection systems that operate independently of the effect of a fire anywhere in the building shall be provided in the control center.

16.15.1.17 HELD-OPEN FIRE DOORS

Fire doors that are normally held open by electromagnetic devices should be released by the activation of any automatic detection, extinguishing, or manual alarm signaling device. Additional information on door requirements may be found in Section 8, Doors and Windows, of this Manual. Maintenance, operation, testing, and equipment shall conform to NFPA 72 and NFPA 70.

16.15.1.18 ELECTRICAL SUPERVISION

The fire alarm system shall be totally supervised. All initiating device circuits (including those for smoke detectors), signal line device circuits, and notification appliance circuits must be electrically supervised. The system shall monitor all electrically supervised circuits. A trouble alarm and visual indicator shall activate upon a single break, open, or ground fault condition which prevents the required normal operation of the system. The trouble signal shall also operate upon loss of primary power (ac) supply, loss of stand-by generator power, low battery voltage, removal of alarm zone module (card, PC board), and disconnection of the circuit used for transmitting alarm signals off-premises. The system shall also provide electrical supervision (capable of detecting any open, short, or ground) for circuits used for supervisory signal services (e.g., sprinkler systems, valves). The fire alarm control panel shall provide supervised relays for HVAC shutdown. An override at the HVAC panel shall not be provided. The fire alarm control panel shall provide the required monitoring and supervised control outputs needed to accomplish elevator recall. All supervisory signals (except for the transmitter disconnect switch provided to allow testing and maintenance of the system without activating the transmitter) shall be transmitted both to the fire station or central station service unit and to the building's fire alarm control panel.

16.15.1.19 EMERGENCY POWER

Emergency power shall be provided for the fire alarm system in accordance with NFPA 72, NFPA 101, and paragraph 16.8 of this section. If an emergency generator is available at the facility meeting the requirements of NFPA 72, then the fire alarm system must be connected to it; otherwise a battery backup with charger, meeting the code requirements specified herein, shall be provided. Emergency power must be able to operate the fire alarm system in the supervisory mode for 48 hours and to operate all alarm devices and system output signals for at least 90 minutes.

16.15.2 SAFETY ALARM SYSTEM

Requirements for this system are as follows.

16.15.2.1 ANNUNCIATOR PANEL

A central safety alarm system annunciator panel that will indicate any abnormal condition shall be designed for the facility. The annunciator panel shall include all relays, switches, and controls, as required for system operation. The basic operation of the panel shall indicate any abnormal condition in a function supervised by the annunciator system, causing the associated indication to flash and the common audible signal to sound continuously. The audible signal can be silenced at any time by the operation of an “acknowledge” push button. The audible signal will automatically sound again with any new indication. The visual signal shall become steady when acknowledged.

16.15.2.2 INDICATING PLATES

Indicating plates shall be red with filled-in place characters. All lamps in the annunciator are tested simultaneously by pressing the remotely mounted “Lamp Test” push button. The annunciator shall indicate the following systems and equipment statuses:

- Fire alarm initiation
- HVAC system motors alarms
- Emergency generator running
- Freezer and cold box temperature alarms
- UPS system failure
- Fume hood and bio-safety cabinet alarms (critical low-flow)
- Location of activated detection, extinguishing or manual alarm device
- Exhaust hood and ventilated cabinet failure alarms (critical low-flow)
- Exhaust systems for instrument and safety cabinet failure alarms (critical low-flow)
- Acid neutralization system alarms
- Power failure
- Incubator temperature alarm
- Gas alarm
- Sensor (gas) alarm
- Laboratory negative pressure failure alarm
- Additional systems to be identified by the agency.

16.15.3 SECURITY SYSTEMS

General requirements and requirements for particular types of systems and facility and site areas are as follows.

16.15.3.1 GENERAL

A complete security system shall be designed for the facility. All security systems shall be operated and monitored from a central point selected by EPA. All security systems shall have a primary and an emergency power source.

16.15.3.1.1 STANDBY BATTERIES

Standby batteries or a UPS shall be furnished to power the system automatically in the event of commercial power failure. If the facility has a generator, batteries shall ensure that there is no loss of power to central equipment until the generator takes over. An alarm shall not be generated when the equipment transfers from AC to DC operation as it does from DC to AC operation. If the facility does not have an emergency generator, sufficient batteries shall be provided to power the controller and necessary devices to prevent unauthorized entry into the building (electronic locks shall stay in the locked position upon power loss but shall still allow emergency egress). Batteries shall be chargeable. If batteries lose charge, an alarm condition shall indicate this at the control console.

16.15.3.2 ACCESS SYSTEMS

A complete building access system shall be designed as an on-line type that reports to a central controller. The professional designing this system shall have at least 3 years of experience in the design of similar installations.

16.15.3.2.1 KEY CARD CONTROL

Key card control shall be provided for all entry to the facility. The key card reader should read key cards with numbering encoded within the card. The card reader shall be capable of operating in an off-line mode to allow persons to enter and exit without recording of card numbers. The card reader shall also be capable of operating in an on-line mode, which causes the card reader to report into a central controller that provides additional security checks on the key card and provides a printout of time, date, card number, etc., for the person entering or leaving the premises. The system shall be of the anti-passback type. In addition, one key access lock and card reader shall be furnished inside the building for every 5,000 square feet of gross floor area (in addition to the vestibules) and at entry to controlled computer areas.

16.15.3.2.2 COMPUTERIZED ACCESS CONTROL SYSTEM

The computerized access control system shall be capable of programming access cards by hour and day. The system shall be designed with 50 percent spare capacity for both card readers and number of cards on the system. Key cards, once removed from the system, shall be replaceable without lowering the integrity of the system or reducing the system's capacity.

16.15.3.2.3 PROXIMITY TYPE CARD READERS

Card readers shall be of the proximity type and shall be suitable for the environment in which they will be located.

16.15.3.2.4 PROGRAMMABLE KEY PAD, SMALL FACILITIES

For very small facilities, a programmable keypad may be used at each entry to control access to the system. The keypad shall be suitable for the environment in which it will be located.

16.15.3.3 INTRUSION DETECTION SYSTEMS

A design professional with a minimum of 3 years' experience in the design of similar installations shall design a complete intrusion detection system. The intrusion detection system shall protect all grade level doors, operable windows, and openings leading into the facility, as well as roof hatches and roof access doors. Operable windows shall be lockable, and accessible windows shall be equipped with an alarm. Roof access doors or hatches shall be secured with heavy-duty hardware and equipped with an alarm. All floor telecommunications closets shall be locked with dead bolt locking devices. In addition to installing perimeter protection, the design professional shall equip a minimum of 10 interior doors with an alarm. It shall be the responsibility of the design professional to coordinate with EPA for the locations of the 10 interior doors to be equipped with the alarms; locations shall be as directed by EPA. Door switches shall be of the balanced magnetic type.

16.15.3.3.1 CENTRAL CONTROL, REMOTELY MONITORED

The entire system shall be monitored at the central control desk of the facility and remotely monitored either on the campus, by an alarm company, or by the local law enforcement agency.

16.15.3.4 SITE ACCESS SYSTEMS

One alarm zone with an infrared beam shall be provided to monitor vehicles passing through the gate of the fenced area. The beam should be positioned to monitor the entire length of the fence on the side with the gate. The alarm zone shall be monitored at the central alarm desk (as part of the intrusion detection system) by remote monitoring of the same type as the intrusion detection system. One zone and an infrared beam detection system shall be provided for each location where there is a gate in the fenced-in area of the site.

16.15.3.5 CLOSED-CIRCUIT TELEVISION SECURITY SYSTEMS

A complete closed-circuit television (CCTV) security system shall be designed. The professional designing this system shall have at least 3 years of experience in the design of similar installations. Conduit and wiring shall be installed for the system and a camera shall be installed at all entrance and exit areas. The location of the camera shall be suitable for monitoring persons' movements when they are entering or leaving the building. An emergency circuit shall provide power for each camera location. Conduit, wiring, cameras, and all other appropriate monitoring equipment shall also be installed in all parking lots, loading docks, and computer areas.

16.15.3.5.1 CAMERAS, FIXED OR PAN-TILT-ZOOM

Cameras shall be of the fixed or pan-tilt-zoom type, low light color, as required for each specific location. Cameras shall be housed in proper enclosures for the environment in which they are to operate (e.g., enclosures with defrosters or heaters, weatherproof enclosures, corrosion-resistant or vandal-proof enclosures).

16.15.3.5.2 CAMERAS, MONITORED AND CONTROLLED

All cameras shall be monitored and controlled at the facility's central control station. Monitors shall be event driven. A recording device shall be provided to record unauthorized access (control by guard). A 120-volt single-duplex receptacle (emergency power) shall be provided immediately next to all CCTV camera locations.

16.15.3.5.3 CCTV SECURITY CAMERAS, LOADING DOCKS

CCTV cameras shall be provided to monitor entry and exit from the loading dock areas. CCTV monitors (in addition to that at the central console for the loading dock areas) shall be provided in the loading dock office to provide identification of delivery vehicles before the loading dock doors are opened.

16.15.3.6 BUILDING PERIMETER SYSTEMS

A complete grade-level perimeter intrusion detection system shall be designed. This system shall be in addition to the intrusion detection system described above and shall be monitored at the same control panel provided for the intrusion detection system.

16.15.3.6.1 ULTRASONIC PROTECTION

Ultrasonic protection should be furnished to protect the grade-level, glass-enclosed office area and any other area that contains exterior glass at grade level. The ultrasonic control panel shall be the type that controls nominally 20 pairs of transmitters and receivers. Input should be connected into the main alarm panels as a separate zone. Sufficient transmitter-receiver pairs shall be installed to protect the entire office area and other grade level areas with exterior glass.

16.15.3.7 DATA PROCESSING

A complete access-intrusion detection system shall be designed for all data processing areas. A card reader and balanced magnetic switch shall be provided at each door leading into the data processing areas. Card readers shall be of the proximity type. The system shall be monitored at the central control station for the facility. The control computer shall be capable of programming access cards by hour and day. The central controller shall also furnish a printout of time, date, card number, etc., for the person entering or leaving the data processing area. The system shall be of the anti-passback type.

16.15.3.7.1 COMPUTER AREA DOORS

If a card access system is being furnished for other doors in the facility, the same cards shall work for the computer area doors (if so encoded for certain personnel).

16.15.3.7.2 CENTRAL CONTROL DOOR MONITORING

The door shall be monitored at the central control station in case it is left open or the card access system is bypassed.

16.15.3.8 PARKING CONTROLS

The parking facility(s) shall be enclosed and equipped with a perimeter sensor system and lockable gates. The gates shall be equipped with a computerized access control system. EPA card readers shall be installed in parallel with any other card readers (if required) on all the access roads.

16.15.3.8.1 ACCESS SYSTEM

The parking control access system shall have all the components discussed above for access systems. For very small facilities, a programmable keypad may be used in lieu of a card reader. The same cards used for building access shall operate the parking controls (if so encoded).

16.15.4 DISASTER EVACUATION SYSTEM

If the facility is located in an area prone to tornados or hurricanes, a warning/evacuation alarm system for the building shall be included. The system shall provide for building evacuation in accordance with the facility's emergency preparedness plan, which shall be coordinated with the community's emergency preparedness plan.

16.15.5 EXIT LIGHTING AND MARKINGS

The requirements for exit lighting and marking are contained in NFPA 101 and the local building code.

- Exit lighting and exit signs shall be provided to clearly indicate the location of exits in conformance with 29 CFR §1910.36 and §1910.37 and the Life Safety Code (NFPA 101). The means of egress, exterior steps, and ramps shall be adequately lighted to prevent accidents.

- Internally illuminated signs shall meet the following criteria:

    - Emergency lighting for the area shall conform to OSHA and the Life Safety Code and shall provide at least 5 footcandles on the sign surface.

    - Exit signs shall be at least 8 inches high by 12½ inches long.

    - Letters shall be at least 6 inches high.

    - The maximum physical distance to a visual sign shall not exceed 100 feet. In addition, an exit sign shall be visible from all points in the corridor.

16.16 Commissioning

Refer to Appendix B of this Manual for the commissioning requirements.

END OF SECTION 16

American Concrete Pumping Association
P.O. Box 4307
1034 Tennessee St.
Vallejo, CA 94590

ACSM **American Congress on Surveying and Mapping**
210 Little Falls St.
Falls Church, VA 22046

ADA **Americans with Disabilities Act**
(For employment questions)
U.S. Equal Employment Opportunity Commission
ADA Legal Services
1801 L St., NW
Washington, DC 20507

(For transportation questions)
U.S. Department of Transportation
Office of Assistant General Counsel for Regulation and Enforcement
400 7th St., SW
Washington, DC 20590

(For public accommodations questions)
U.S. Department of Justice
Office of Americans with Disabilities Act
P. O. Box 66118
Washington, DC 20035-6118

(For telecommunications questions)
Federal Communications Commission Consumer Assistance
1919 M St., NW
Washington, DC 20554

(For architectural accessibility questions)
Access Board
1331 F St., NW, Suite 1000
Washington, DC 20004-1111

AGA **American Gas Association, Inc.**
1515 Wilson Blvd.
Arlington, VA 22209

AGC **Associated General Contractors of America**
1957 East St., NW
Washington, DC 20006

AHA **American Hardboard Association**
520 N. Hicks Rd.
Palantine, IL 60067

AHLI **American Home Lighting Institute**
435 N. Michigan Ave., Suite 1717
Chicago, IL 60611

AHMA **American Hardware Manufacturers Association**
931 N. Plum Grove Rd.
Schaumburg, IL 60173

AI **Asphalt Institute**
Asphalt Institute Building
College Park, MD 20740

AIA **American Institute of Architects**
1735 New York Ave., NW
Washington, DC 20006

AIA / NA **Asbestos Information Association/ North America**
1745 Jefferson Davis Hwy., Suite 509
Arlington, VA 22202

AIHA **American Industrial Hygiene Association**
2700 Prosperity Ave., Suite 250
Fairfax, VA 22031

AIC **American Institute of Constructors**
20 S. Front St.
Columbus, OH 43215

AISC **American Institute of Steel Construction, Inc.**
One East Wacker Drive, Suite 3100
Chicago, IL 60601-2001

AISI **American Iron and Steel Institute**
1101 17th St., NW, Suite 1300
Washington, DC 20036

AITC **American Institute of Timber Construction**
7012 S. Revere Parkway, Suite 140
Englewood, CO 80112

ALSC **American Lumber Standards Committee**
P.O. Box 210
Germantown, MD 20875-0210

AMCA **Air Movement and Control Association**
30 West University Dr.
Arlington Heights, IL 60004

ANL **Argonne National Laboratory**
9800 South Cass Ave.
Argonne, IL 60439

ANS **American Nuclear Society**
555 North Kensington Ave.
LaGrange Park, IL 60525

ANSI **American National Standards Institute**
25 West 43rd Street, 4 floor
New York, NY 10036

APA **APA - The Engineered Wood Association**
P.O. Box 11700
Tacoma, WA 98411-0800

APA **Architectural Precast Association**
6710 Winkler Road, Suite 8
Ft. Myers, FL 33919

APFA **American Pipe Fitting Association**
8136 Old Keene Mill Rd., #B-311
Springfield, VA 22152

API **American Petroleum Institute**
1220 L. St., NW
Washington, DC 20037

AREMA **American Railway Engineering and Maintenance of Way Association**
8201 Corporate Drive, Suite 1125
Landover, MD 20785

ARI **Air-Conditioning and Refrigeration Institute**
1501 Wilson Blvd., 6th Floor
Arlington, VA 22209

ARMA **Asphalt Roofing Manufacturers Association**
6288 Montrose Road
Rockville, MD 20852

ARTBA **American Road and Transportation Builders Association**
1010 Massachusetts Avenue, NW
Washington, DC 20001-5402

ASA **Acoustical Society of America**
500 Sunnyside Blvd.
Woodberry, NY 11797

or

American Subcontractors Association
1004 Duke St.
Alexandria, VA 22314

ASC **Adhesive and Sealant Council, Inc.**
1500 Wilson Blvd., Suite 515
Arlington, VA 22209-2495

or

Associated Specialty Contractors
7315 Wisconsin Ave.
Bethesda, MD 20814

ASCC **American Society of Concrete Construction**
426 S. Westgate
Addison, IL 60101

ASCE **American Society of Civil Engineers**
1801 Alexander Bell Drive
Reston, VA 20191

ASHRAE **American Society of Heating, Refrigerating, and Air-Conditioning Engineers , Inc.**
1791 Tullie Circle, NE
Atlanta, GA 30329

ASID **American Society of Interior Designers**
1430 Broadway
New York, NY 10018

ASME **American Society of Mechanical Engineers**
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASPE **American Society of Professional Estimators**
3617 Thousand Oaks Blvd., Suite 210
Westlake, CA 91362

ASSE **American Society of Sanitary Engineers**
P.O. Box 40362
Bay Village, OH 44140

ASTM **American Society for Testing and Materials**
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

AWCI **Association of the Wall and Ceiling Industries International**
25 K St., NE, Suite 300
Washington, DC 20002

AWI **Architectural Woodwork Institute**
2310 S. Walter Reed Dr.
Arlington, VA 22206

AWS **American Welding Society, Inc.**
550 N.W. LeJeune Rd.
Miami, FL 33126

AWWA **American Water Works Association**
6666 West Quincy Ave.
Denver, CO 80235

BHMA **Builder's Hardware Manufacturers Association, Inc.**
60 E. 42nd St., Room 511
New York, NY 10165

BIA **The Brick Industry Association**
11490 Commerce Park Dr.
Reston, VA 20191-1525

BMRI **Building Materials Research Institute, Inc.**
501 5th Ave., #1402
New York, NY 10017

BRB **Building Research Board**
2101 Constitution Ave., NW
Washington, DC 20418

BSC **Building Systems Council**
1201 15th Street, NW
Washington, DC 20005

BSI **Building Stone Institute**
420 Lexington Ave., Suite 2800
New York, NY 10170

CDA **Copper Development Association**
260 Madison Ave.
New York, NY 10016

CERC **Coastal Engineering Research Center**
U.S. Army Corps of Engineers
P.O. Box 631
Vicksburg, MA 39180

CFR **Code of Federal Regulations**
Superintendent of Documents
Government Printing Office
Washington, DC 20402

CGA **Compressed Gas Association**
4221 Walney Road, 5th Floor
Chantilly, VA 20151-2923

CGMI **Ceramic Glazed Masonry Institute**
P.O. Box 35575
Canton, Ohio 44735

CIEA **Construction Industry Employers Association**
625 Ensminger Rd.
Tonawanda, NY 14150

CIMA **Construction Industry Manufacturers Association**
111 E. Wisconsin Ave., Suite 940
Milwaukee, WI 53202-4879

CISCA **Ceilings and Interior Systems Construction Association**
1500 Lincoln Hwy., Suite 202
St. Charles, IL 60174

CISPI **Cast Iron Soil Pipe Institute**
1499 Chain Bridge Rd., Suite 203
McLean, VA 22101

CLFMI **Chain Link Fence Manufacturers Institute**
10015 Old Columbia Road, Suite B-215
Columbia, MD 21046

CMAA **Crane Manufacturers Association of America**
1326 Freeport Road
Pittsburgh, PA 15238

CPMA **Construction Products Manufacturing Council**
P.O. Box 21008
Washington, DC 20009-0508

CRA **California Redwood Association**
405 Enfrente Dr., Suite 200
Novato, CA 94949

CRI **Carpet and Rug Institute**
P.O. Box 2048
Dalton, GA 30722-2048

CRSI **Concrete Reinforced Steel Institutes**
933 N. Plum Grove Rd.
Schaumburg, IL 60173

CSI **Construction Specifications Institute**
601 Madison St.
Alexandria, VA 22314

CSSB **Cedar Shake & Shingle Bureau**
P.O. Box 1178
Sumas, WA 98295-1178

CTI **Ceramic Tile Institute**
700 N. Virgil Ave.
Los Angeles, CA 90029

or

Cooling Tower Institute
P.O. Box 73383
Houston, TX 77273

DFI **Deep Foundations Institute**
326 Lafayette Avenue
Hawthorne, NJ 07506

DHI **Door and Hardware Institute**
7711 Old Springhouse Rd.
McLean, VA 22101-3474

DIPRA **Ductile Iron Pipe Research Association**
245 Riverchase Parkway E., Suite 0
Birmingham, AL 35244

DOE **U.S. Department of Energy**
1000 Independence Ave., SW
Washington, DC 20585

DOE/OSTI **DOE/Office of Scientific and Technical Information**
P.O. Box 62
Oak Ridge, TN 37831

DOT **U.S. Department of Transportation**
400 7th St., SW
Washington, DC 20590

EIA **Electronics Industries Association**
2001 Eye St., NW
Washington, DC 20006

EIMA **Exterior Insulation Manufacturers Association**
Box 75037
Washington, DC 20013

EO **Executive Orders**
National Archives and Records Administration
8th St. and Pennsylvania Ave., NW
Washington, DC 20408

EPA **Environmental Protection Agency**
1200 Pennsylvania Avenue, NW
Washington, DC 20460

ESCSI **Expanded Shale, Clay and Slate Institute**
6218 Montrose Rd.
Rockville, MD 20852

FCC **Federal Construction Council**
Building Research Board
National Research Council
2101 Constitution Ave., NW
Washington, DC 20418

FEMA **Federal Emergency Management Agency**
Federal Center Plaza
500 C St., SW
Washington, DC 20472

FGMA **Flat Glass Marketing Association**
White Lakes Professional Building
3310 Harrison St.
Topeka, KS 66611

FHA **Federal Housing Administration**
451 7th St., SW, Rm. 3158
Washington, DC 20410

FIPS **Federal Information Processing Standards**
National Bureau of Standards
Room 64-B, Technology
Gaithersburg, MD 20899

FM **Factory Mutual Engineering and Research**
1151 Boston-Providence Turnpike
Norwood, MA

FPL **Forest Products Laboratory**
USDA Forest Service
One Gifford Pinchot Dr.
Madison, WI 53705-2398

FPS **Forest Products Society**
2801 Marshall Ct.
Madison, WI 53705-2295

FR **Federal Register**
Superintendent of Documents
U.S. Government Printing Office
710 North Capitol St., NW
Washington, DC 20402

FS **Federal Specifications**
Attention: NPFC Code 1052
Naval Publications and Forms Center
5801 Tabor Ave.
Philadelphia, PA 19120-5099

GA **Gypsum Association**
1603 Orrington Ave., Suite 1210
Evanston, IL 60201

GBCA **General Building Contractors Association**
36 S. 18th St.
P.O. Box 15959
Philadelphia, PA 19103

GSA **General Services Administration**
Public Buildings Service
1800 F St., NW
Washington, DC 20405

HPVA **Hardwood Plywood and Veneer Association**
P.O. Box 2789
Reston, VA 20195

IAEA **International Atomic Energy Agency**
Vienna International Center
Wagranerstrasse 5
Post Fach 100
A-1400 Vienna, Austria

IALD **International Association of Lighting Designers**
18 E. 16th St., Suite 208
New York, NY 10003

IAPMO **International Association of Plumbing and Mechanical Officials**
20001 Walnut Drive S.
Walnut, CA 91789

ICAA **Insulation Contractors Association of America**
15819 Crabbs Branch Way
Rockville, MD 20855

ICC **International Code Council**
5203 Leesburg Pike
Suite 600
Falls Church, VA 22041

ICEA **Insulated Cable Engineers Association**
P.O. Box 1568
Carrollton, Georgia 30112

ICRP **International Commission on Radiological Protection**
Maxwell House
Fairview Park
Elmsford, NY 10523

IEEE **Institute of Electrical and Electronics Engineers**
345 E. 47th St.
New York, NY 10017

IES **Institute of Environmental Sciences**
940 East Northwest Highway
Mount Prospect, IL 56056

IESNA **Illuminating Engineering Society of North America**
120 Wall Street, Floor 17
New York, NY 10005

IFI **Industrial Fasteners Institute**
1505 E. Ohio Building
Cleveland, OH 44114

IHEA **Industrial Heating Equipment Association**
3900 N. Fairfax Drive, Suite 400
Arlington, VA 222093

IILP **International Institute of Lath and Plaster**
P.O. Box 1663
Lafayette, CA 94549

ILIA **Indiana Limestone Institute of America**
Stone City Bank Building, Suite 400
Bedford, IN 47421

IMI **International Masonry Institute**
823 15th St., NW, Suite 1001
Washington, DC 20005

ISDI **Insulated Steel Door Institute**
30200 Detroit Road
Cleveland, Ohio 44145-1967

LANL **Los Alamos National Laboratory**
P.O. Box 1663
Los Alamos, NM 87545

LBL **Lawrence Berkeley Laboratory**
1 Cyclostron Road
Berkeley, CA 94720

LLNL **Lawrence Livermore National Laboratory**
7000 East Ave.
Livermore, CA 94550

LPI **Lightning Protection Institute**
3335 N. Arlington Hts. Rd., Suite E
Arlington Hts., IL 60004

MBMA **Metal Building Manufacturers Association**
1300 Sumner Avenue
Cleveland, OH 44115-2851

MCAA **Mason Contractors Association of America**
33 South Roselle Road
Schaumburg, IL 60193

or

Mechanical Contractors Association of America
5410 Grosvenor, Suite 120
Bethesda, MD 20814

MIA **Marble Institute of America**
33505 State St.
Farmington, MI 48024

MFMA **Maple Flooring Manufacturers Association**
60 Revere Dr., Suite 500
Northbrook, IL 60062

MLSFA **Metal Lath/Steel Framing Association**
600 S. Federal, Suite 400
Chicago, IL 60605

MSS **Manufacturers Standardization Society of the Valve and Fittings Industry**
127 Park St., NE
Vienna, VA 22180

NBMDA **North American Building Material Distributors Association**
1701 Lake Ave., Suite 170
Glenview, IL 60025

NAAMM **National Association of Architectural Metal Manufacturers**
600 South Federal St.
Chicago, IL 60605

NACE **NACE International**
P.O. Box 201009
Houston, TX 72216-1009

NADC **National Association of Demolition Contractors**
4415 W. Harrison St.
Hillside, IL 60162

or

National Association of Dredging Contractors
1625 I St., NW, Suite 321
Washington, DC 20006

NAEC **National Association of Elevator Contractors**
4053 LaVista Rd., Suite 120
Tucker, GA 30084

NAFCD **National Association of Floor Covering Distributors**
401 North Michigan Avenue
Suite 2400
Chicago, IL 60611-4267

NAHB **National Association of Home Builders**
1201 15th Street, NW
Washington, DC 20005

NAHRO **National Association of Housing Redevelopment Officials**
630 Eye Street, NW
Washington, DC 20001

NAPA **National Asphalt Pavement Association**
6811 Kenilworth Ave., Suite 620
P.O. Box 517
Riverdale, MD 20737

NAPHCC **National Association of Plumbing, Heating, and Cooling Contractors**
P.O. Box 6808
Falls Church, VA 22046

NARSC **National Association of Reinforcing Steel Contractors**
10382 Main St.
P.O. Box 225
Fairfax, VA 22030

NASA **National Aeronautics and Space Administration**
300 E St., SW
Washington, DC 20546

NAVFAC **U.S. Naval Facilities Engineering Command**
Attention Cash Sales/Code 1051
Naval Publications and Forms Center
5801 Tabor Ave.
Philadelphia, PA 19120-5099

NAWIC **National Association of Women in Construction**
327 S. Adams St.
Fort Worth, TX 76104

NBMA **National Building Manufacturers Association**
142 Lexington Ave.
New York, NY 10016

NBS **National Bureau of Standards**
(currently National Institute of Standards and Technology)

NCA **National Constructors Association**
1101 15th St., NW, Suite 1000
Washington, DC 20005

NCMA **National Concrete Masonry Association**
13750 Sunrise Valley Drive
Herndon, VA 20171

NCRP **National Council on Radiation Protection and Measurement**
7910 Woodmont Ave., Suite 800
Bethesda, MD 20814

NCSBCS **National Conference of State Building Codes and Standards**
481 Carlisle Dr.
Herndon, VA 22070

NEC **National Electrical Code**
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269

NECA **National Electrical Contractors Association**
7315 Wisconsin Ave.
13th Floor, West Building
Bethesda, MD 20814

NEMA **National Electrical Manufacturers Association**
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209

NESC **National Electrical Safety Code**
Institute of Electrical & Electronics Engineers, Inc.
345 East 47th St.
New York, NY 10017

NFPA **National Fire Protection Association**
1 Batterymarch Park
PO Box 9101
Quincy, MA 02269

or

National Forest Products Association
1250 Connecticut Ave., NW, Suite 200
Washington, DC 20036

NGA **National Glass Association**
8200 Greensboro Dr., Suite 302
McLean, VA 22101

NIH **National Institutes of Health**
U.S. Dept. of Health and Human Services
9000 Rockville Pike
Bethesda, MD 20892

NIJ **National Institute of Justice**
633 Indiana Ave., NW
Washington, DC 20531

NIOSH **National Institute of Occupational Safety and Health**
200 Independence Ave., SW
Room 715H
Washington, DC 20201

NH&RA **National Housing & Rehabilitation Association**
1625 Massachusetts Avenue, NW
Suite 601
Washington, DC 20036-4435

NKCA **National Kitchen Cabinet Association**
P.O. Box 6830
Falls Church, VA 22046

NLA **National Lime Association**
200 North Glebe Road, Suite 800
Arlington, Virginia 22203

NLBMDA **National Lumber and Building Material Dealers Association**
40 Ivy St., SE
Washington, DC 20003

NOAA **National Oceanic and Atmospheric Administration**
Washington Science Center, Building 5
6010 Executive Blvd.
Rockville, MD 20852

NOFMA **National Oak Flooring Manufacturers Association**
P.O. Box 3009
Memphis, TN 38173-0009

NPA **National Particleboard Association**
2306 Perkins Pl.
Silver Spring, MD 20910

NPCA **National Paint and Coatings Association**
1500 Rhode Island Ave., NW
Washington, DC 20005

or

National Precast Concrete Association
10333 North Meridian St., Suite 272
Indianapolis, IN 46290

NRC **U.S. Nuclear Regulatory Commission**
Publications Division
Washington, DC 20555

NRCA **National Roofing Contractors Association**
1 O'Hare Center
6250 River Rd.
Rosemont, IL 60018

NRMCA **National Ready Mixed Concrete Association**
900 Spring St.
Silver Spring, MD 20910

NSA **National Security Agency/ Central Security Service**
Fort Meade, MD 20755

or

National Stone Association
1415 Elliot Pl., NW
Washington, DC 20007

NSF **NSF International**
P.O. Box 130140
789 N. Dixboro Road
Ann Arbor, MI 48113-0140

NSPC **National Standard Plumbing Code**
Published by: National Association of Plumbing-Heating-Cooling Contractors
P.O. Box 6808
Falls Church, VA 22040

NSPE **National Society of Professional Engineers**
1420 King St.
Alexandria, VA 22314-2794

NTIA **National Telecommunications and Information Administration**
Main Commerce Building
Washington, DC 20230

NTIS **National Technical Information Service**
5485 Port Royal Rd.
Springfield, VA 22161

NTMA **National Terrazzo and Mosaic Association**
3166 Des Plaines Ave., Suite 132
Des Plaines, IL 60018

NWMA **National Woodwork Manufacturers' Association**
400 W. Madison St.
Chicago, IL 60606

NWWDA **National Wood Window and Door Association**
1400 East Touhy Ave., Suite 450
Des Plaines, IL 60018

OMB **Office of Management and Budget**
Old Executive Office Building
Washington, DC 20503

OPCMIA **Operative Plasterers' and Cement Masons' International Association of the United States and Canada**
1125 17th St., NW, 6th Floor
Washington, DC 20036

OSHA **Occupational Safety and Health Administration**
U.S. Department of Labor
200 Constitution Ave., NW
Washington, DC 20201

PLCA **Pipe Line Contractors Association**
1700 Pacific Avenue, Suite 4100
Dallas, Texas 75201-4675

PCA **Portland Cement Association**
5420 Old Orchard Rd.
Skokie, IL 60077

PCI **Precast/Prestressed Concrete Institute**
209 W. Jackson Blvd.
Chicago, IL 60606-6938

PDCA **Painting and Decorating Contractors of America**
7223 Lee Highway
Falls Church, VA 22046

PDI **Plumbing and Drainage Institute**
1106 W. 77th St. Dr.
Indianapolis, IN 46260

PHCIB **Plumbing-Heating-Cooling Information Bureau**
303 E. Wacker Dr., Suite 711
Chicago, IL 60601

PMI **Plumbing Manufacturers Institute**
800 Roosevelt Rd., Building C, Suite 20
Glen Ellyn, IL 60137

PPI **Plastics Pipe Institute**
355 Lexington Ave.
New York, NY 10017

PTI **Post-Tensioning Institute**
8601 North Black Canyon Highway
Suite 103
Phoenix, AZ 85021

RCRC **Reinforced Concrete Research Council**
5420 Old Orchard Rd.
Skokie, IL 60077

RFCI **Resilient Floor Covering Institute**
401 E. Jefferson Street, Suite 102
Rockville, MD 20850

SAMA **Scientific Apparatus Makers Association**
225 Reinekers Lane, Suite 625
Alexandria, VA 22314

SBA **Systems Builders Association**
P.O. Box 117
West Milton, OH 45383

SCS **Soil Conservation Service**
U.S. Department of Agriculture
14th St. and Independence Ave., SW
Washington, DC 20250

SDI **Steel Deck Institute**
P.O. Box 25
Fox River Grove, IL 60021

or

Steel Door Institute
30200 Detroit Road
Cleveland, Ohio 44145-1967

SIGMA **Sealed Insulating Glass Manufacturers Association**
111 E. Wacker Dr., Suite 600
Chicago, IL 60601

SJI **Steel Joist Institute**
3127 10^{th} Ave. North Ext.
Myrtle Beach, SC 295776760

SMA **Screen Manufacturers Association**
2850 South Ocean Boulevard, #114
Palm Beach, FL 33480-6205

or

Stucco Manufacturers Association
2402 Vista Nobleza
Newport Beach, CA 92660

SMACNA **Sheet Metal and Air Conditioning Contractors National Association**
4201 Lafayette Center Drive
Chantilly, Virginia 20151-1209

SMWIA **Sheet Metal Workers International Association**
1750 New York Ave., NW
Washington, DC 20006

SNL **Sandia National Laboratories**
P.O. Box 5800
Albuquerque, NM 87185

SPRI **Single Ply Roofing Institute**
77 Rumford Avenue, Suite 3B
Waltham, MA 02453

SSFI **Scaffolding, Shoring, and Forming Institute, Inc.**
1230 Keith Building
Cleveland, OH 44115

SSPC **Steel Structures Painting Council**
4400 5th Ave.
Pittsburgh, PA 15213

SBIC **Sustainable Buildings Industry Council**
1331 H Street, NW, Ste. 1000
Washington, DC 20005

SWI **Sealant and Waterproofers Institute**
3101 Broadway, Suite 300
Kansas City, MO 64111

or

Steel Window Institute
1230 Keith Building
Cleveland, OH 44115

TCA **Tile Council of America**
100 Clemson Research Blvd.
Anderson, SC 29625

or

Tilt-Up Concrete Association
PO Box 204
Mt. Vernon, IA 52314

TCAA **Tile Contractors Association of America, Inc.**
4 East 113th Terrace
Kansas City, MO 64114

TIMA **Thermal Insulation Manufacturers Association**
7 Kirby Plaza
Mount Kisco, NY 10549

UL **Underwriters Laboratories Inc.**
333 Pfingsten Rd.
Northbrook, IL 60062

USACE **U.S. Army Corps of Engineers**
441 G Street, NW
Washington, DC 20314

USAF **U.S. Air Force**
Manuals may be ordered from
headquarters of any Air Force Base

VMA **Valve Manufacturers Association of America**
1050 17th St., NW, Suite 701
Washington, DC 20036

WMA **Wallcovering Manufacturers Association**
355 Lexington Ave.
New York, NY 10017

WEF **Water Environment Federation**
601 Wythe St.
Alexandria, VA 22314-1994

WRC **Water Resources Council, Hydrology Committee**
U.S. Department of the Interior
C St. between 18th & 19th Sts., NW
Washington, DC 20240

WRI **Wire Reinforcement Institute**
PO BOX 450
Findlay, OH 45839-0450

WWPA **Western Wood Products Association**
Yeon Building
522 SW 5th Ave.
Portland, OR 97204

END OF APPENDIX A

supplier's support is required. The integrated commissioning process should have the distinct phases outlined below.

B1.2.1 PRE-DESIGN PHASE

The objectives of this phase are to document the owner's vision, requirements and future expectation for the facility, select the Commissioning Authority, document the initial design intent, and begin development of the Commissioning Plan. The roles and responsibilities of the owner, the Project Manager, design team, the Commissioning Authority and contractors must be defined for the commissioning process.

During pre-design, the commissioning team should include the EPA Project Manager, the Commissioning Authority, and the design team. The main commissioning tasks of the pre-design phase include:

- The EPA Project Manager should send out requests for qualifications for commissioning services, develop the scope of the commissioning effort, and select a Commissioning Authority and design team.
- The Commissioning Authority assembles the commissioning team and develops a draft design phase commissioning plan.
- The Commissioning Authority recommends the commissioning roles and scope for all members of the design and construction teams.
- The Commissioning Authority reviews the design intent for clarity and completeness.
- The Commissioning Authority delivers a draft design phase commissioning plan and comments on the Design Intent document.

B1.2.2 DESIGN PHASE

The goals of commissioning during the Design Phase are to ensure that the concepts for building systems developed during pre-design are included in subsequent design phases; that the design record document is updated; and that commissioning is adequately reflected in the contract documents. During the design phase, there are four primary commissioning activities: developing the Basis of Design and expanding design intent as necessary; performing commissioning-focused design reviews(s); expanding and modifying the Commissioning Plan to include the construction phase; and developing commissioning specifications for the construction phase. The main design phase commissioning tasks are outlined below:

- The Commissioning Authority updates the design phase commissioning plan started during pre-design phase.

- The design team develops Basis of Design documentation. The Commissioning Authority reviews this documentation for clarity, completeness, constructability and compliance with the EPA's design intent. In addition, all changes to the initial design intent must be documented, reviewed, and approved by the Commissioning Authority and EPA.

- The Commissioning Authority attends selected design team meetings and formally reviews and comments on the design at 15%, 35%, 65% and 100% stages of development. Potential system performance problems, energy-efficiency improvements, indoor environmental quality issues, operation and maintenance issues, and other issues should be addressed in these design reviews. The Commissioning Authority ensures that the design follows and meets the original design intent. The Commissioning Authority also makes recommendations to facilitate commissioning and improve building performance.

- The Commissioning Authority, in cooperation with the A/E team, develops detailed commissioning specifications to be included by the design team in the final contract document. The commissioning specifications detail the commissioning process and the scope of work for all participants including contractors and vendors. The specifications comprise commissioning-related requirements that will be the contractor's responsibility, including equipment installation and start-up, documentation, and functional testing.

- While writing the specifications for Commissioning, the Commissioning Authority develops a Preliminary Commissioning Plan. This plan becomes a scope of work that names actual components and systems in the design documents. The Commissioning Authority shall develop procedures for each of the systems to be commissioned. This interim plan should be incorporated into the specifications to give contractors the best possible idea of his part in the process. In addition, the

Commissioning Authority shall recommend enhanced language regarding training, documentation, installation, and system checkout for inclusion in non-commissioning sections of the specifications.

- The commissioning provider compiles and updates the design records as design progresses.

- The Commissioning Authority shall deliver regular commissioning progress reports and comments and recommendations from design reviews to EPA project manager. The Commissioning Authority shall submit updates of the design records, initial construction phase commissioning plan and commissioning specifications.

- The review performed by the Commissioning Authority shall determine that the documents are consistent with the design intent, specify commissionable systems, include inspection and testing details, include equipment parameters that can be verified, incorporate a layout that allows testing and maintenance and fully describe the Commissioning process for the contractors. The Commissioning Authority will also review the contract documents to confirm that each piece of equipment or system is capable of being tested and has objective performance parameters that can be confirmed.

The EPA Project Manager shall monitor the design phase process and shall make certain that procedures are in place within the team so issues the Commissioning Authority raises are reviewed and the team comes to a consensus. If a consensus cannot be reached on an issue, the team should document the issue, and EPA should provide a decision and direction in consultation with the appropriate design professional.

1.2.3 BIDDING/CONTRACT NEGOTIATION PHASE

The Commissioning Authority will participate in the pre-bid conference presenting a brief overview of the commissioning process and answer specific questions posed by the Contractors. The Commissioning Authority may review bids, alternates, and addendums to ensure that commissioning and the Owner's Project Requirements are not compromised by the changes.

1.2.4 CONSTRUCTION PHASE

The main construction phase commissioning tasks are listed below:

- The Commissioning Authority will update the construction phase commissioning plan, which includes a list of all systems and specific equipment and components to be commissioned, the process to be followed, communications, reporting and documentation protocols, and an estimated schedule for the commissioning process. The final draft of the Commissioning Plan will be completed during the early stages of construction after all equipment submittals have been approved and before equipment has arrived on the site. The Plan will start with the requirements on a system-by-system basis and on the actual design and the equipment ordered. The Commissioning Plan developed at this point will have detailed information on the support required from contractor and responsible subcontractor personnel.

- The Commissioning Authority will coordinate a construction phase commissioning kickoff meeting that include the EPA project manager, construction manager, design team, Commissioning Authority, and respective representatives from the general contractor and mechanical, electrical, controls, and TAB subcontractors. At this meeting, the Commissioning Authority outlines the roles and responsibilities of each project team member, specifies procedures for documenting commissioning activities and resolving issues, and reviews the preliminary construction phase commissioning plan and schedule.

- The Commissioning Authority will attend periodic planning meetings to update parties involved in commissioning. During the initial stages of construction, the commissioning provider may attend regular construction meetings and hold a line item on the agenda. Later in construction the commissioning provider may coordinate entire meetings devoted to commissioning issues.

- The Commissioning Authority will develop and keep a record of issues and findings throughout the construction phase commissioning process that require further attention, tracking, or correction.

- The Commissioning Authority reviews and comments on contractor submittals of equipment to be commissioned during the normal submittal review process and forward them to the EPA Project Manager and designer.

- The Commissioning Authority should assist the EPA Project Manager in monitoring the development of coordination drawings to ensure interface between trades.
- The Commissioning Authority reviews the O&M manual to ensure that it complies with the specifications, is complete, clear, and is well organized and accessible for use by the O&M staff.
- The Commissioning Authority will visit the construction site periodically, note any conditions that might affect system performance or operation and provide construction observation reports.

1.2.4.1 FIELD VERIFICATION

The Field Verification phase of commissioning starts when the Commissioning Plan is completed, equipment is ordered, and construction begins. The Field Verification phase lays the foundation for equipment startup by confirming that installed equipment can function in a safe and effective manner.

The Commissioning Authority will develop and provide construction checklists for installation, start-up and initial checkout of the equipment and systems to the contractor for execution. These checklists will also incorporate manufacturers' requirements. The Commissioning Authority will witness some of the start-up execution and will spot-check selected items on the checklist prior to functional testing. The contractor will execute construction checklists provided by the Commissioning Authority and equipment manufacturer and submit them to the Commissioning Authority for review before functional testing begins.

1.2.4.2 FUNCTIONAL PERFORMANCE TESTING

Functional performance testing is conducted to verify that the performance of all integrated systems meets the specified objectives defined in the Design Intent. Functional performance testing ensures that equipment and systems are installed correctly, tested, and adjusted so that they operate efficiently and according to design intent under a variety of conditions. This testing is intended to document the completion and performance of all components, equipment and systems.

Functional performance testing should progress from functional verification to performance verification in sequence, from individual equipment or components through subsystem operation to complete systems. At the end of the testing, every mode of building and system operation, all system equipment, system interfaces, and every item in the control sequence description will be proven operational under all normal operational modes including load, in all seasons, and under abnormal or emergency conditions.

a. Functional Verification
Equipment is to be started up for the first time with required factory representatives in attendance. The equipment should be tested at all required speeds and preliminary programming should be completed as required to allow subsequent safe and easy starting.

- The Commissioning Authority will develop written test procedures manage, witness, and document the functional tests, with the actual hands-on execution of the test procedures typically carried out by subcontractors, particularly the controls contractor.
- Acceptable performance is reached when equipment or systems meet specified design parameters under full-load and part-load conditions during all modes of operation, as described in the commissioning test requirements of the specifications and commissioning plan (some testing will be completed by monitoring system operation over time through the building automation system or data loggers a few weeks after occupancy).
- The Commissioning Authority will not re-test systems that have been tested and approved by regulatory authorities. The Commissioning Authority will prepare test plans, assist with execution and document tests of commissioned equipment overseen by regulatory authorities.
- The Commissioning Authority should assist in the programming of the BAS to include the trend logging of a selected group of key performance indicators. These indicators include temperatures and pressures for boiler and chiller operations, duct pressures, outside airflows, and some typical variable air volume terminals operating parameters, and unitary equipment performance parameters.

b. Performance Verification
After equipment has been proved at startup, the Commissioning Authority to confirm that the pieces work together will conduct Functional Performance Tests, which are the heart of the Commissioning process.

- Functional tests will include checking BAS parameters, such as programmed addresses, sensor calibration factors, occupied/unoccupied programming, and trend logging. Programming charts, sequences of operation, block wiring diagrams, and wiring termination diagrams should be included in the report. All BAS tuning variables, such as response times, damping variables, delays, and interlocks, should be included in the report. Laboratory and other critical facilities will have the control input and output points loop calibrated (inputs will be simulated with signal generators).

- The subcontractor's Testing, Adjusting, and Balancing report will be checked for accuracy by sampling the report data. If a substantial failure rate is encountered, all failures should be corrected and a different sample chosen for a repeat test. The EPA project manager may elect to have the Commissioning Authority to perform TAB.

- As Functional Performance Tests proceed, the Commissioning Authority may find a number of items that do not appear to work as intended. The Commissioning Authority will need to perform a varying amount of re-testing because of system and equipment failures during the initial testing. The amount of retesting that is paid for by the EPA and the amount that is passed back to the Contractor should be very clearly spelled out in the construction contract.

- The Commissioning Authority will verify the accuracy of facility record drawings.

1.2.4.3 FINAL AND POST ACCEPTANCE PHASE

When the requirements of the contract documents and Commissioning Plan have been completed and satisfactorily documented and any additional required documentation has been completed, submitted to the design professionals, and accepted, the Commissioning Authority should recommend Final Acceptance of the building and all building systems. The recommendation is issued subject to any outstanding issues or deficiencies that cannot be resolved until a future date.

The Post-Acceptance Phase is an important step in ensuring the effective, ongoing functioning of a facility's building systems. As use and function of facilities change, the building systems need to be adapted to the changing requirements of occupancy and utilization. It is appropriate to maintain a history of the facility, recording changes and verifying the effect on the previously commissioned systems.

The Post-Acceptance Phase includes the completion of any outstanding functional performance tests, a post-construction review, at a set or variable period after construction, evaluation and verification that the design intent of the building is still being met and ongoing monitoring.

Post-acceptance commissioning is the continued adjustment, optimization, and modification of the HVAC system to meet specified requirements. It includes updating documentation to reflect minor set point adjustments, system maintenance and calibration, major system modifications, and provision of ongoing training of operations and maintenance personnel. The objective of post-acceptance commissioning is to maintain the performance of the building systems throughout the useful life of the facility in accordance with the current design intent.

A post-construction review should be scheduled a set number of years after completion of construction or in response to significant changes in the facility structure, equipment or in the use of the facility. As-built documents must be revised to reflect modifications made to any part of the facility or the building systems. Any change in usage, installed equipment, loads, or occupancy must be carefully monitored and documented. In addition, any system servicing and maintenance problems should be documented. If the variations are significant enough to warrant a recommissioning of the individual systems, or as a method of continued maintenance, an earlier review should be conducted.

1.2.4.4 DOCUMENTATION

The Commissioning Authority develops the following documentation during construction phase:

- Updated construction commissioning plan
- Updated commissioning schedule
- Minutes from commissioning meetings
- Commissioning progress reports
- Reports of submittal reviews
- Updates to the commissioning issues
- Construction checklists and functional test forms
- Report of training completion
- Report of O&M manual review
- Systems Manual
- Commissioning Records.

1.2.5 WARRANTY REVIEW AND SEASONAL TESTING

The successful completion of commissioning should be a requirement for the issuance of the Final Certificate for Payment. The commissioned building should provide the working environment required for the occupants and the O&M staff can concentrate on establishing an effective Preventive Maintenance Program that should work for the life of the building.

The certain parts of the building mechanical system cannot be adequately tested due to the season of the completion. The commissioning plans should include off-season testing to allow testing certain equipment under the most appropriate test conditions. The systems should also be tested during the spring and fall seasons for partial load performance of mechanical systems.

The commissioning contract should provide the EPA with the ability to engage the Commissioning Authority for occasional, informal consultations throughout the warranty period or during approximately the first year of building operation.

1.2.6. FINAL COMMISSIONING REPORT

By the completion of training the Commissioning Authority should have completed the Commissioning Final Report. This report should contains copies of the following:

- Design Intent
- Basis of design
- Pre-functional checklists complete
- Functional checklists complete
- TAB reports
- System schematics
- Control strategies and set points
- Deficiency log
- Guidelines for energy accounting.

The Commissioning Final Report, the TAB report, the O&M manuals, and the record drawings and specifications form the documentation that will be left with the O&M staff. Additional information on building controls that includes block-wiring diagrams; as-built control diagrams and sequences of operation will also be included in either the Commissioning Final Report or the O&M manual.

1.2.7. O&M STAFF TRAINING AND DOCUMENTATION

The Commissioning Authority will have a significant positive impact on O&M training:

- Recommend the necessary O&M staffing (total personnel, qualifications, and required shifts) to satisfy the Owner's operational intent.

- Develop a facility preventive maintenance plan. This task is directly tied to the development of the O&M staffing. The Commissioning Authority shall develop a facility preventive maintenance plan making best use of O&M staffing.

- The Commissioning Authority shall reviews the operation and maintenance manuals and verifies that they are complete and available for training sessions. Prepare framed instructions showing the sequence of operations and interoperability for major systems and component.

- The Commissioning Authority ensures that the contractor uses adequate training plans and that the training is completed per the contract documents. The Commissioning Authority should provide training agendas to the contractor's/manufacturer's trainers to review and use.
- The Commissioning Authority shall compile a Systems Manual consisting of the design record; space and use descriptions; single line drawings and schematics for major systems; control drawings; sequences of control; a table of all set points and implications when changing them; time-of-day schedules; instructions for operation of each piece of equipment for emergencies, seasonal adjustment, startup and shutdown; instructions for energy savings operations and descriptions of the energy savings strategies in the facility; recommendations for recommissioning frequency by equipment type; energy tracking recommendations; and recommended, standard trend logs with a brief description of what to look for in them. The Systems Manual with O&M Manuals will form the Master O&M Manual.
- The Commissioning Authority shall prepare a recommended list of spare parts, bench stock, and special tools/equipment required for the first year of building operation.
- The Commissioning Authority shall deliver a final commissioning report, summarizing the commissioning effort with the Commissioning Authority's view on each piece of commissioned equipment relative to installation and start-up, functional performance, O&M documentation, and training. The Commissioning Record also contains the commissioning plan, functional tests, individual commissioning reports, reviews, and issues log.

1.2.8. COMMISSIONING PROCESS MATRIX

Task	Description	Documents
Commissioning Authority Selection	Develop an RFP for commissioning services.	RFP Format Scope of Work Scoring Matrix
Commissioning Contract	Negotiate, prepare and execute a commissioning contract.	Commissioning Contract
Design Team Kickoff Meeting	Initial ""Kickoff Meeting" with the Design Team to establish the purpose and proposed process for commissioning the facility and to establish the individual roles.	Design Commissioning Plan
Owner Performance Requirements (OPR)	In cooperation with the EPA and the Design Team, the Commissioning Authority prepares a design intent summary document.	Owners Performance Requirements (OPR) Summary
Basis of Design	The design team prepares a Basis of Design document.	Draft Basis of Design
35% Plan Review	Complete thorough reviews of the 35% plan documents and submitted criteria (engineering calculations, system selection and major component selection).	Comments
65% Plan Review	Review 65% Design Documents (zoning requirements, specifications, typical room layouts, system main layouts, riser layouts, standard details, schedules and coordination requirements). Draft Construction Commissioning Plan, Commissioning Specifications and Supplemental Commissioning Language for other sections.	Comments Draft Commissioning Plan, Commissioning Specifications
95% Plan Review	Review 95% Design Documents Updated Commissioning Plan, Final Commissioning Specifications .	Commissioning Specifications Draft Construction Commissioning Plan

Task	Description	Documents
Pre-bid Meeting and Assistance During Bidding process.	Pre-bid meeting to assist contractors in answering any questions about the systems or the commissioning process.	Written Responses or Recommendations
Construction Commissioning Kick-off meeting	An initial commissioning meeting with all contractors and commissioning team members to establish the purpose and proposed process for commissioning this facility.	Final Commissioning Plan with specific individual responsibilities identified.
Duration Schedule for Commissioning Activities	Duration schedule for the contractors for the commissioning activities required by the commissioning plan.	Duration Schedule
Submittal & Shop Drawing Review	Review all pertinent approved shop drawings to support the Commissioning Process. Submittals & Shop drawings will be reviewed for commissionability, maintainability and for compliance to the OPR.	Commissioning Review Log
Construction Commissioning Plan	The final commissioning plan will incorporate all changes established by review with EPA and the design team. The final commissioning plan will also include complete FIV, OPT and FPT protocols for each system.	Final Construction Commissioning Plan FIV, OPT and FPT documents and protocols.
Field Inspection Verifications (FIV)	Inspect the progress of construction with respect to the systems being commissioned; verify that the construction complies with the plans & specifications and construction quality practices.	FIV Check Sheets, Daily Log, Commissioning Issues Log
Commissioning Team Meetings	Commissioning meetings on a regular basis with the commissioning team to review progress of the commissioning effort and reinforce individual responsibilities.	Commissioning Issues Log
Complete all FIV's	Complete all field inspection verifications.	FIV check sheets, Commissioning Issues Log
Operational Performance Tests (OPT)	Observe or facilitate all equipment and system start up procedures. The Contractor will execute all start up and point-to-point tests and the Cx will witness execution of all OPT's.	Completed OPT's, Commissioning Issues Log
Functional Performance Tests (FPT)	Observe and facilitate all FPT testing. FPT's shall be designed by the Commissioning Authority and performed by the contractors.	FPT Check Sheets, Commissioning Issues Log
Operator Training	Work with the contractor and owner to schedule and plan training activities so that training occurs in a coordinated and coherent fashion. Contractors and vendors provide all training.	Coordinated Training Agendas
Prepare Final Commissioning Report	Based on the accumulated commissioning work completed as described above, assemble the data into a final commissioning report.	Final Commissioning Report
Deferred (Off season) Testing	Conduct any testing required by the commissioning plan that was deferred from the acceptance period.	Warranty Commissioning Plan, FPT Test check sheets

Task	Description	Documents
Ten-Month Warranty Visit	Inspect the site and interview building operating personnel to identify any outstanding warranty failures and to identify any persistent equipment failure issues that should be handled within the warranty period.	Commissioning Warranty Issues Log, Commissioning report addenda

1.3 PREVENTIVE OPERATION AND MAINTENANCE PROGRAM

In order to maintain equipment reliability and optimize facility operation after building turnover, Commissioning Authority should develop a customized preventive operations and maintenance program. The goal of a Preventive Maintenance Plan is to improve equipment reliability and increase equipment life. A functional Operation & Maintenance Plan optimizes facility operation to provide significant energy savings and comfort benefits.

The Commissioning Authority should be a valuable training source not only for the specifics of operating and maintaining the commissioned equipment, but also for providing the background information needed to assist the EPA's O&M staff in understanding system operations and being able to apply practical preventive maintenance functions.

1.4. RETRO COMMISSIONING AND CONTINUOUS COMMISSIONING

Retro commissioning is a systematic, documented process that identifies low-cost O&M improvements in an existing building and brings that building up to the design intentions of its current usage. Retro commissioning identifies and solves comfort and operational problems, explores the full potential of the facility's energy management system, and ensures that the equipment performs properly after space changes have been made.

The retrocommissioning process is a project-specific effort. Each project's focus and goals depend on the needs of the EPA, the budget, and the condition of the facility and equipment. Retro commissioning most often focuses on:

- Reducing energy and demand costs
- Bringing equipment to its proper operational state
- Reducing occupant complaints
- Improving indoor environmental quality
- Reducing premature equipment failures
- Improving facility operation and maintenance procedures

Retro commissioning project typically occurs in four distinct phases: Planning, Investigation, Implementation, and Project Hand-off.

The primary tasks for the Planning Phase are developing internal goals and objectives and support for the project, selecting and hiring a retro commissioning service provider, assemble the team that will see the project through to completion and develop the retro-commissioning plan.

The primary goals of the Investigation Phase are to understand current operation and maintenance, to identify issues and potential improvements, and to select the most cost-effective ones for implementation. Tasks during investigation should include:

- Interviewing management and building personnel
- Reviewing current O&M practices and service contracts
- Spot testing equipment and controls and trending or electronic data logging of pressures, temperatures, power, air and water flows, and lighting levels and use
- Gather and review facility documentation
- Begin Assessment and Complete Simple Repairs, begin Master List of Potential Improvements
- Develop Diagnostic Monitoring and Test Plans. The retro-commissioning service provider should direct the functional performance tests and assess and analyze the findings.
- Develop an Initial List of Findings
- Assemble an interim report describing the findings and recommendations.

The Implementation Phase activities include Implementation of the major cost-effective repairs and Improvements and verification of results (re-test and monitor).

In the Project Hand-off Phase the retro commissioning process is completed. The final report should include the following:

- Executive summary
- The retro commissioning plan
- The Master List of Findings with a description of the improvements implemented
- A cost/benefits analysis and the actual improvement costs
- A list of capital improvements recommended for further investigation
- The BAS trending plan and logger diagnostic / monitoring plan and results
- All completed functional tests and results
- Recommended frequency for re commissioning
- Documentation of strategies adopted to optimize systems operation
- Updated (or Created) Building Documentation

The retro commissioning service provider either should provide the training or ensure that the contractor/manufacturer provides adequate training for operating staff and perform deferred testing (seasonal testing).

Continuous commissioning is similar to retro-commissioning and begins by identifying and fixing HVAC and comfort problems in the building. In the continuous commissioning, when the commissioning is complete, the team continues to work together to monitor and analyze building performance data provided by permanently installed metering equipment. This process works to ensure that the savings achieved from the commissioning continue to persist over time.

1.5 COMMISSIONING AND LEED™ BUILDING RATING

Fundamental building systems commissioning is a prerequisite for LEED™ building rating and requires having a contract in place to implement the following fundamental best practice commissioning procedures:

- Engage a commissioning team that does not include individuals directly responsible for project design or construction management.
- Review the design intent and the basis of design documentation.
- Incorporate commissioning requirements into the construction documents.
- Develop and utilize a commissioning plan.
- Verify installation, functional performance, training and operation and maintenance documentation.
- Complete a commissioning report.

Additional System Commissioning has 1 credit point allocated and in addition to the Fundamental Building Commissioning prerequisite implement the following commissioning tasks:

- A Commissioning Authority independent of the design team shall conduct a review of the design prior to the construction documents phase.
- An independent Commissioning Authority shall conduct a review of the construction documents near completion of the construction document development and prior to issuing the contract documents for construction.
- An independent Commissioning Authority shall review the contractor submittals relative to systems being commissioned.
- Provide the owner with a single manual that contains the information required for re-commissioning building systems.
- Have a contract in place to review building operation with O&M staff, including a plan for resolution of outstanding commissioning-related issues within one year after construction completion date.

1.6 DEFINITIONS

Commissioning Authority - An independent party with no affiliation to the design team or participating contractors, who implements the overall commissioning process.

Design Intent - Design Intent defines the benchmark by which the success of a project is judged. It describes EPA's program for the planned facility, explains the rationale behind the ideas, concepts and criteria for the facility. The Design Intent document is updated and increased in detail with each phase of the design. The initial Design Intent document is a detailed explanation of the facilities objectives and its functional and operational needs, occupancy requirements, general quality of materials and construction, intended levels and quality of environmental control, performance criteria, environmental needs and budget considerations and limitations. The Design Intent document is the starting point for the development of the Basis of Design. A

Design Intent document is written by the design team in consultation with the EPA and with an input from the Commissioning Authority.

Basis of Design **-** The documentation of the primary thought processes and assumptions behind design decisions that are made to meet the Design Intent. It shall respond to, and be consistent with, performance criteria specified in the Design Intent document (Some reiteration of the design intent may be included). The Basis of Design is written by the design team and describes codes, standards, operating conditions, and design conditions, weather data, interior environmental criteria, other pertinent design assumptions, cost goals, and references to applicable codes, standards, regulations and guidelines. The Basis of Design increases in detail as the design progresses. The Commissioning Authority reviews, comments on, and approves the design progress submissions.

The commissioning specifications provide the bidders with a clear description of the extent of the required verification test. They detail what to test, under which conditions to test, acceptance testing criteria and acceptable test methods. The documentation, reporting, and scheduling requirements for verification testing is also to be included. The verification procedures, which are developed, should include all functional performance tests, including the following at a minimum:

- Testing, adjusting, and balancing test performance
- Equipment performance
- Performance of subsystems consisting of combinations of equipment (such as refrigeration cycle, pumps, chillers, cooling towers, and interconnecting piping)
- Performance of the automatic controls in all seasonal modes
- Integrated system performance
- Performance of all life safety devices and systems as they interface with the subsystems
- Architectural and structural system performance
- Electrical system performance
- Plumbing system performance
- Required operation and maintenance training by the contractor, for the owner, his O&M staff and other relevant staff and the facility's O&M documentation requirements.

Commissioning Plan is a document, or group of documents, that defines the commissioning process at the various stages of project development. The plan must create a procedure that will verify and provide documentation that the performance of the building and its individual systems meet the owner's requirements.

Design Phase Commissioning Plan - The commissioning plan developed during the pre-design phase which outlines each team member's role and responsibilities, sets protocols for communication and reviews, specifies procedures for documenting commissioning activities and resolving issues, and sets the schedule for commissioning activities during the design phase of the project. This plan should develop the extent of the commissioning process and communicate it to all project participants

Construction Phase Commissioning Plan - An extension of the commissioning plan developed during the design phase, which outlines the roles and responsibilities of each project team member, specifies procedures for documenting commissioning activities and resolving issues, and sets a schedule for conducting commissioning activities during the construction phase of the project. It is updated as construction progresses.

Construction Checklist - A checklist to ensure that the specified equipment has been provided, properly installed, and initially started and checked out adequately in preparation for full operation and functional testing (e.g., belt tension, fluids topped, labels affixed, gages in place, sensors calibrated, voltage balanced, rotation correct).

Functional Tests - Tests that evaluate the function and operation of equipment and systems using direct observation or monitoring methods. Functional testing is the assessment of the system's ability to perform within the parameters set up in the Basis of Design. Systems are tested under various modes, such as during low cooling or heating loads, high loads, component failures, unoccupied, varying outside air temperatures, fire alarm, power failure, etc. The systems are run through all the control system's sequences of operation to determine whether they respond as the sequences state. Functional tests are performed after construction checklists are complete.

Performance Metrics - verification that a specific element in the Design Intent has been met. Performance Metrics are identified throughout the design of the project with as many as possible being generated during the development of the Design Intent. The design team and Commissioning Authority are responsible for Performance Metrics development.

LEED™ - a voluntary, consensus-based, market-driven building rating system, which was created to provide a complete framework for assessing building performance and meeting sustainability goals based on well-founded scientific standards. The LEED™ rating system is organized into five environmental categories. One of them - Energy & Atmosphere – has prerequisites and number of credits allocated to building commissioning.

Appendix C - Room Data Sheets

C.1 General

This section contains the sample room data sheets for various typical functional layouts for EPA laboratories and laboratory support spaces. These data sheets should be used as guides and references during the programming and design process of a specific project. Final laboratory layouts must be developed with the individual users and their research requirements as provided in Section 1, General Requirements, as well as in other related sections of this Manual. Specific criteria and requirements should be verified by the design team with EPA, local, state, and federal regulatory agencies.

C.2 Typical Room Requirements

C.2.1 ROOM DATA SHEETS

The room data sheets for typical room arrangements are shown in the following laboratory and laboratory support room layouts. Specific requirements, developed during the programming process with the individual user of the room, shall be in accordance with Section 1, General Requirements, as well as in other relative sections, of this Manual. The final layouts for these areas will be the responsibility of the design professional with approval by EPA.

C.2.2 STANDARDS AND SYMBOLS

Standard requirements for each area or room, as indicated in the various sections of this Manual, must also be defined for each specific laboratory facility Program of Requirements (POR). A listing and definitions of typical standard requirements, symbols, and abbreviations are provided in the following subsections as examples.

C.3 Definition of Standard Requirements

All standard requirements shall be in accordance with codes and with all other requirements of this document. The narrative and illustrative description of requirements in this section and elsewhere in this Manual shall take precedence over drawings. If an item is described in the narrative but not shown in a drawing, that is not to be taken as a waiver of the requirement. The schematic drawings are provided for illustrative purposes only.

C.3.1 LABORATORY CLASSIFICATION STANDARD

The required construction for all laboratory units shall be classified as Fire Hazard Class B laboratories per NFPA 45.

C.3.2 ARCHITECTURAL STANDARDS

Refer to General Requirements, Section 1, and other relative sections in this Manual for the architectural standards to be utilized in EPA projects.

C.3.3 MECHANICAL STANDARDS

Refer to Special Construction, Section 13, and Mechanical Requirements, Section 15, of this Manual for the fire protection and mechanical standards to be utilized in EPA projects.

C.3.4 ELECTRICAL STANDARDS

Refer to Electrical Requirements, Section 16, of this Manual for the fire alarm and electrical standards to be utilized in EPA projects.

C.4 Laboratory Symbols List

Room data sheets and design drawings shall be prepared utilizing the following graphic symbols for laboratory modules as they apply to a specific project.

PLUMBING SYMBOLS

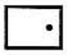
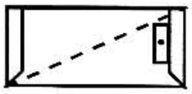
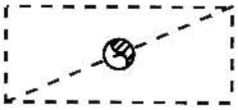
A	AIR, COMP. (100 PSIG U.O.N.)	HW	HOT WATER
LA	AIR, LAB (15 PSIG U.N.O)		CUP SINK
CO2	CARBON DIOXIDE		LAB SINK
RO	REVERSE OSMOSIS WATER	FD	FLOOR DRAIN
SS	SAFETY SHOWER	FLD	FUNNEL DRAIN
CW	COLD WATER	FO	FLOOR SINK
CHWS	CHILLED WATER SUPPLY		SHUT-OFF VALVE
CHWR	CHILLED WATER RETURN	EW	EYE WASH

ELECTRICAL SYMBOLS

S_D	DIMMER SWITCH		JUNCTION BOX
	20A SGL REC 120V	W	WARNING LIGHT
	20A DUPLEX REC 120V		LIGHT FIXTURE
	30A SGL REC 208V SINGLE PHASE	S	SAFE LIGHT
	30A SGL REC 120■ 208V SINGLE PHASE		DISC SWITCH
	20A SGL REC 208V 3 PHASE		TELEPHONE
	SPECIAL PWR ERC	WP	WEATHERPROOF
	PEDESTAL BOX WITH REC	EP	EXPLOSION PROOF
	SURFACE RACEWAY	EM	EMERGENCY CKT
			COMPUTER OUTLET

C.4 Laboratory Symbols List (Continued)

ARCHITECTURAL SYMBOLS

	Cup Sink
	Epoxy Sink
	Stainless Steel Sink
	Fume Hood
	Biological Safety Cabinet
	Government Furnished Equipment
	Umbilical 5" x 18"
	Snorkle 150 cfm Exhaust (U.N.O.)

COUNTERTOP MATERIALS

E	Epoxy Top
P	Acid Resistant Plastic Laminate
S	Stainless Steel

APPENDIX C
TYPICAL LABORATORY ROOM EXAMPLES

EXAMPLE 1	1 MODULE LABORATORY
EXAMPLE 2	2 MODULE LABORATORY
EXAMPLE 3	3 MODULE LABORATORY

ROOM DATA SHEETS

The following information shall be provided for each laboratory space.

SPACE TYPE
Information given to generally describe type of laboratory space by function.

AREA
Information provided as part of a specific space requirement for a particular project.
Example is used to illustrate a Typical 1-Module Laboratory.

SPACE NAME
Information provided as part of specific description of space usage for a particular project.

ACTIVITY / PROGRAM NAME
Information provided to assign responsibility for a specific space to a particular Branch / Section for a project.

OCCUPANCY
Identifies number of personnel in a given space for a defined period of time.

BUILDING SECTION
Identifies functional grouping in which space is to be located.

ADJACENCIES
Information is to be developed during programming by the design professional in consultation with representative facility users and with approval by EPA.

OPERATION / TASK DESCRIPTION
Information is to be developed during programming by the design professional in consultation with representative facility users and with approval by EPA.

LIST OF REQUIREMENTS

Ceiling – height and type

Doors – size and type

Flooring – material

Walls – materials and finishes

Window Treatment

Special Construction – if required

Outfitting

Fixed Laboratory Equipment – list of casework requirements such as:
- Metal Casework - "C" Frame
- LF of Base Cabinets - 36 Inches High
- LF of Wall Cabinets - Glass Door
- LF Adjustable Wall Shelving - 2 Tier
- Epoxy Top

- Fume Hood with Services
- Vented Solvent Storage Cabinet Below Hood
- Vented OSHA Cabinet (30 Gallon)
- Laboratory Sink
- Cup Sink
- Laboratory Desks with Bookshelves, Tackboards and File with Storage Cabinets

Mechanical Service Requirements
- Temperature and Humidity Control
- 100 Percent Supply and Exhaust - 24 Hour-Operation

Electrical Service
- 120V/20 Amp AC at Fume Hood
- 120V/20 Amp Receptacles 24 Inches on Center in Raceway
- 208V/30 Amp-1 Phase, 4 Wire AC at Fume Hood
- Disconnect Switch at Door for 120/208V Laboratory Power
- Telephone
- Cable Tray
- Emergency Power
- Fluorescent Lighting - 100 Footcandles at 36 Inches AFF
- Security
- Computer Outlets

Plumbing/Fire Protection
- Industrial Hot and Cold Water, Sink
- Industrial Cold Water, Cup Sink
- Deionized Water
- Laboratory Drain (Acid Waste)
- Compressed Air, 15 psi Serrated Connection
- Nitrogen Cylinder
- Laboratory Vacuum
- Water Sprinklers
- Dry Chemical and Carbon Dioxide Extinguisher in Safety Niches
- Safety Shower/Eyewash Station

CHEMICALS USED IN THIS ROOM

Types and quantities used are to be identified during programming by the design professional in consultation with representative facility users and with approval by EPA. The following is used as an example:
Small quantities of organic solvents, acids, and bases (generally less than 1 gallon of each at any one time) in concentrations ranging from weak solutions to concentrated materials. Standard reagent chemicals in gram proportions.

MOVABLE EQUIPMENT & FURNISHINGS

List of Government Furnished/Government Installed (GFGI) equipment and furnishings is to be identified during programming by the design professional in consultation with representative facility users and approval by EPA. The following is used as an example:

- Analytical Balances
- Bench Top Drying Ovens
- Refrigerators
- Other

EXAMPLE 1
1 MODULE LABORATORY

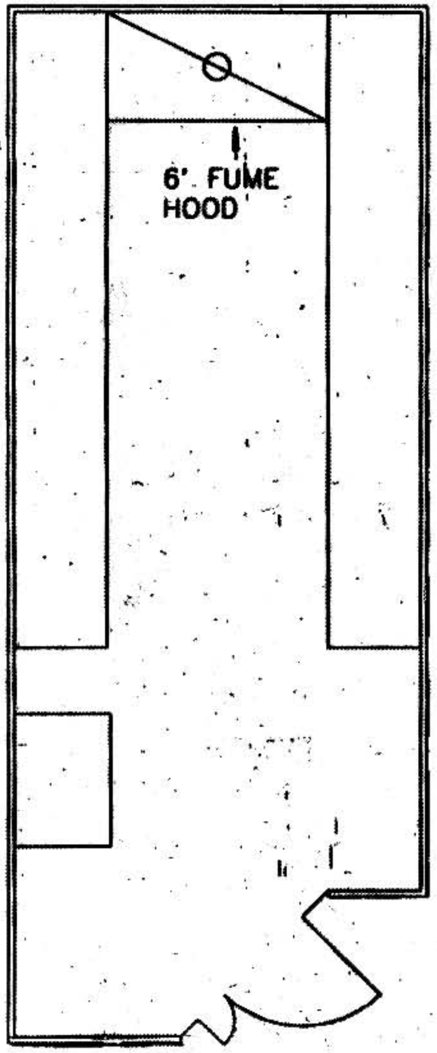


Figure 1

ROOM DATA SHEET

1 MODULE / 1 FUME HOOD

EXAMPLE 2
2 MODULE LABORATORY

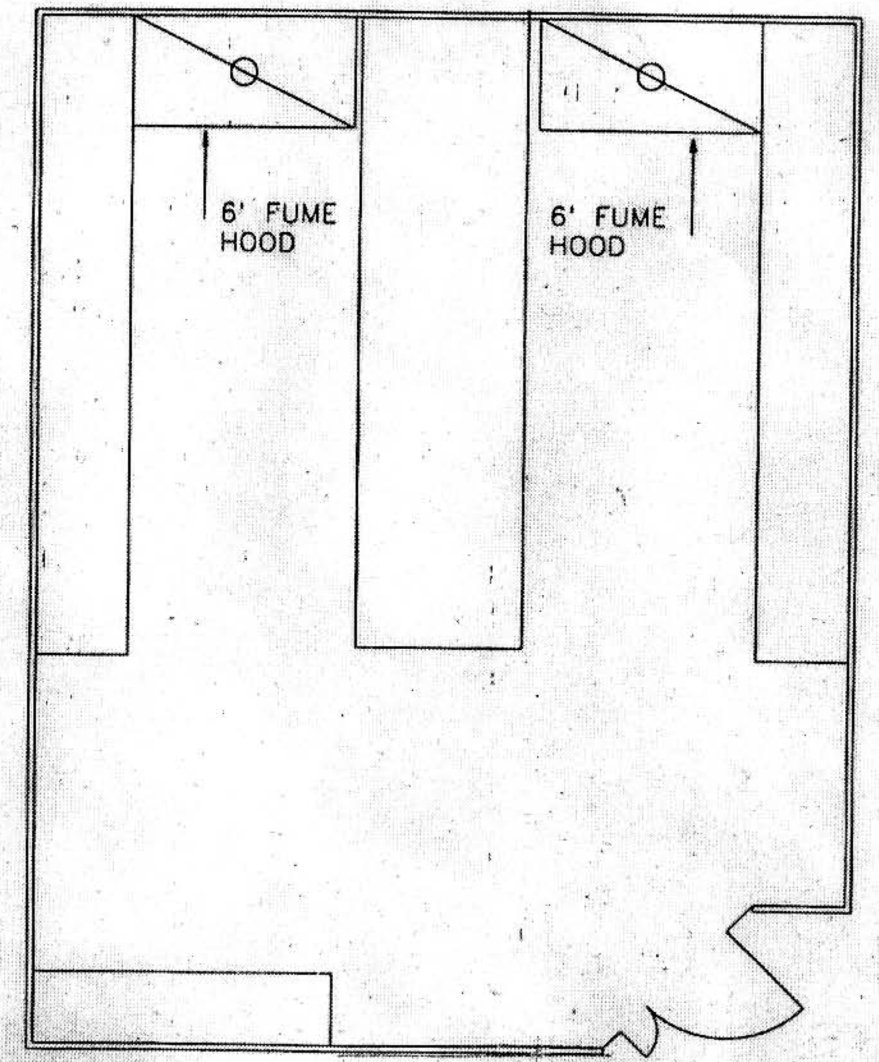


Figure 3

ROOM DATA SHEET

2 MODULES / 2 FUME HOODS

EXAMPLE 3
3 MODULE CHEMISTRY LABORATORY

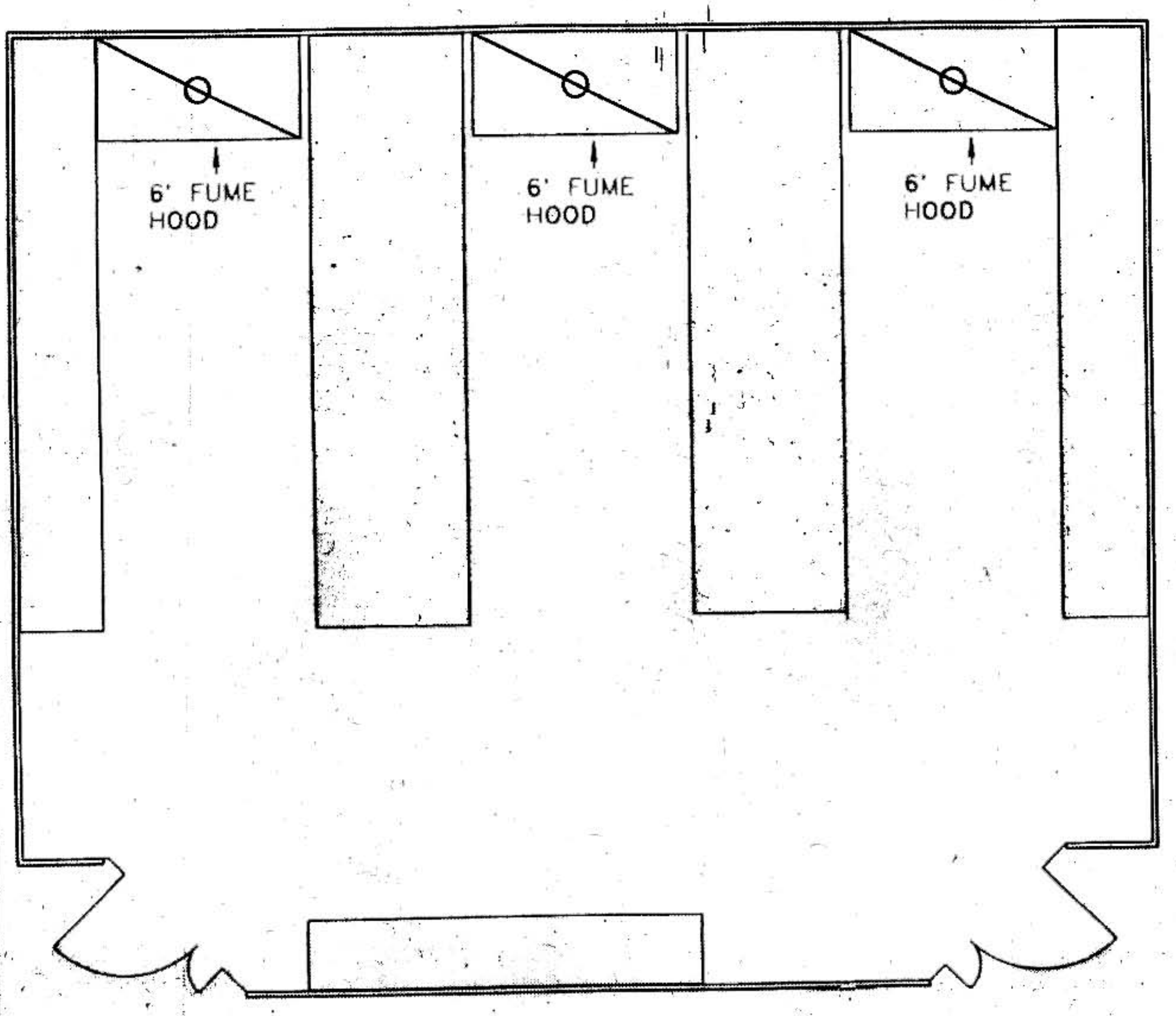


Figure 6

ROOM DATA SHEET

3 MODULES / 3 FUME HOODS

END OF APPENDIX C

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFCs	chlorofluorocarbons
cfm	cubic feet per minute
C-Frame	cantilevered frame
CGA	Compressed Gas Association
CISPI	Cast Iron Soil Pipe Institute
CFR	Code of Federal Regulations
CMD	Contracts Management Division
CMU	concrete masonry unit
COR	Contracting Officer's Representative
CPSC	Consumer Products Safety Commission
CPVC	chlorinated polyvinyl chloride
CRF	critical radiant flux
CTI	Ceramic Tile Institute; Cooling Tower Institute
CVTS	cabled video teleconference space
db	dry bulb
dB	decibels
dBA	decibels of sound measured on an A-scale
DC	direct current
DDC	direct digital controls
DHHS	Department of Health and Human Services
DI	deionized water
DOP	dioctyl phthalate
DOT	U.S. Department of Transportation
DTD	Developmental Toxicology Division
EA	Environmental Assessment
ECAO	Environmental Criteria and Assessment Office
EERD	Ecosystem Exposure Research Division
EIS	environmental impact statement
EM	engineering memorandum
EMCS	energy management control system
EMF	electromagnetic fields
EMS	energy management system
EMT	electrical metallic tubing
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ESD	Emission Standards Division
ETD	Environmental Toxicology Division
°F	degrees Fahrenheit
°F db	degrees Fahrenheit dry bulb
FAA	Federal Aviation Administration
FFL	carpet pill test
FGCC	Federal Geodetic Control Committee
FM	Factory Mutual
FMSD	Facilities Management and Services Division
fpm	feet per minute
GC/MS	gas chromatograph/mass spectrometer
GDHS	geometric design of highways and streets
GECD	Global Emission and Control Division
gpm	gallons per minute
GPS	Global Positioning System
GSA	General Services Administration
GTD	Genetic Toxicology Division
HAZMAT	hazardous materials

HCFC	hydrochlorofluorocarbon
HD	heavy duty
HEFRD	Human Exposure and Field Research Division
HEPA	high-efficiency particulate aerosol
HERL	Health Effects Research Laboratory
HFC	hydrofluorocarbon
HID	high-intensity discharge
HMSF	hazardous materials/waste storage facility
hp	horsepower
HP	high pressure
HPLC	high-performance liquid chromatography
HRMD	Human Resources Management Division
HTW	high-temperature water
HVAC	heating, ventilation, and air-conditioning
IAQ	indoor air quality
IBM	International Business Machines
IBC	International Building Code
ICC	International Code Council
ICS	Industrial Controls and Systems
ICP	inductively coupled plasma
ICSSC	Interagency Committee on Seismic Safety in Construction
ID	inside diameter
IPCEA	Insulated Power Cable Engineer's Association
"K" Rated	transformers specially constructed for use with nonlinear loads
kV	kilovolt
kVa	kilovolt - ampere
kwd	kilowatt demand
kwh	kilowatt hours
LAN	local area network
LCC	life cycle cost
LCCA	life cycle cost analysis
LEL	lower flammable/explosive limit
LEEDS	Leadership in Energy and Environmental Design Green Building Rating System
LIMS	Laboratory Information Management Systems
low E glass	low emissivity glass
MBMA	Metal Building Manufacturers Association
MDF	main distribution frame
MEF	main entrance frame
µg/L	micrograms per liter
mg/L	milligrams per liter
MIL-F	Military Federal Specification
MRDD	Methods Research and Development Division
MS	mass spectrometer
MSDS	material safety data sheets
N value	number of blows per linear foot
NAAQS	National Ambient Air Quality Standards
NACE	NACE International
NAD	North American Datum
NAVD	North American Vertical Datum
NC	noise criteria
NCF	network control facility
NC/LC	noncombustible/limited combustible
NCMA	National Concrete Masonry

	Association
NCPD	National Contracts Payment Division
NDPD	National Data Processing Division
NEBB	National Environmental Balancing Bureau
NEC	National Electrical Code
NEHRP	National Earthquake Hazard Reduction Program
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NGVD	National Geodetic Vertical Datum
NIOSH	National Institute of Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NRC	noise reduction coefficient
NSC	National Safety Code
NSF	National Sanitation Foundation
NSPC	National Standard Plumbing Code
NTD	Neurotoxicology Division
NUSF	net usable square feet
OAQPS	Office of Air Quality Planning and Standards
OAR	Office of Air and Radiation
OARM	Office of Administration and Resources Management
OD	Office of the Director; outside diameter
ODF	ozone depletion factor
OID	Owners Insurance Underwriters
ORD	Office of Research and Development
OSA	outside air ventilation systems
OSHA	Occupational Safety and Health Administration
PB	polybutylene
PBX	private branch exchange
pCi/L	picocuries per liter
PCI	Precast Concrete Institute
PCI-MNL	Precast Concrete Institute Manual
PDU	power distribution unit
ph	phase
plf	pounds per linear foot
POR	program of requirements
psf	pounds per square foot
psi	pounds per square inch
psig	pounds per square inch gauge
PTI	Post-Tensioning Institute
PURPA	Public Utility Regulatory Policies Act
PVC	polyvinyl chloride
PVDF	polyvinylidine fluoride
QATSD	Quality Assurance and Technical Support Division
R (values)	thermal resistance
RCRA	Resource Conservation and Recovery Act
RD	relative humidity
RSD	Research Support Division
RTECS	Registry of Toxic Effects of Chemical Substances
SCS	Soil Conservation Service
SDR-PR	standard dimension ratio - pressure rated
SDWA	Safe Drinking Water Act
SEFA	Scientific Equipment and Furniture Association

SFPB	Sustainable Facilities Practices Branch
SFO	solicitation for offer
SHEMD	Safety, Health and Environmental Management Division
SHEMP	Safety, Health and Environmental Management Program
SMACNA	Sheet Metal and Air-Conditioning Contractors National Association
SNAP	Significant New Alternatives Policy
STC	sound transmission class
STL	sound transmission loss
TC	telecommunication closet
TIA	traffic impact analysis
TM	technical memorandum
TSD	Technical Support Division
U-factor	a coefficient of heat loss
UFAS	Uniform Federal Accessibility Standards
UL	Underwriters Laboratories Inc.
UPS	uninterruptible power supply
UTP	unshielded twisted pair
VAV	variable air volume
VOA	volatile organic analysis
VCP	visual comfort probability
VCR	video cassette recorder
wb	wet bulb

END OF APPENDIX D

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