U.S. Environmental Protection Agency

Facilities Manual, Volume II

A/E Guidelines

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DRAFT

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1. GENERAL REQUIREMENTS

The U.S. Environmental Protection Agency's (EPA's) *Facilities Manual* is comprised of four distinct, yet complementary, resources for planning and managing 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 andHealth Manual: Safety and Health Requirements* (Safety Manual) outlines safety and health considerations for owned or leased EPA facilities. The Safety Manual's goal is to maintain a safe and healthful workplace that protects against injury, illness, and loss of life.

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

All of the volumes have been updated to incorporate the most recent federal and agency-specific requirements.

These A&E Guidelines contain a compilation of architectural and engineering standards and guidelines to be used in the design and construction of new EPA facilities (including additions and alterations). The guidance and information presented herein must be used in conjunction with Volumes 3 and 4. These A&E Guidelines are also intended to be used as resources for developing 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 these A&E Guidelines is to establish a consistent, agency-wide level of quality and excellence in the planning, design, and construction of all EPA facilities-related projects. It is not intended to deter use of more stringent or greater performance criteria. Architects, engineers, contractors, and other professionals supporting EPA facilities projects shall determine any additional requirements not covered in these A&E Guidelines for their particular projects. It is the responsibility of these professionals to verify which requirements must be attained for a particular project, and to develop a strategy for achieving the relevant requirements.

Adherence to the A&E Guidelines does not relieve the architects and engineers 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 architects and engineers involved in the design of a particular EPA-owned and/or -operated 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, and the provisions of these A&E Guidelines.

Citations of standards, codes, or references within these A&E Guidelines should be assumed to refer to the most recent edition. Years and publication dates specifically stated in the A&E Guidelines reflect the version in use when the Guidelines were written and published. When using these A&E Guidelines, the user should verify that the documents referenced are the most recent and have not been superseded.

1.1 General Design Requirements

This document contains design standards and criteria for new buildings and major and minor alterations in existing facilities. This chapter identifies general technical requirements, and provides general guidance for actual building layouts. 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 may also be consulted.

The design of EPA facilities may adhere to the following general principles:

- Meet the specified program requirements while being functional and flexible—capable of keeping pace with the changes that are continually occurring in EPA programs

- Comply with the requirements of this Manual, and relevant national, state and local building codes and standards, including where applicable the International Building Code (IBC)

- Provide a high degree of energy efficiency and demonstrate sustainable design principles

- Provide visual quality in overall design and natural use befitting of the dignity, enterprise, vigor, and stability of the American Government.

1.1.1 Functionality

A building that functions as it is intended is the underpinning of a quality "whole" building. There are three overarching principles associated with ensuring functional building design and operations:

- Accounting for spatial needs is a primary element of the planning process that translates to an owner's spatial and service requirements for a building or facility. This process seeks to establish goals; collect and analyze facts; establish functional relationships; uncover and test concepts; determine needs; and state the problem. There is also a need to design for flexibility of programmed space.

- A successfully designed building that functions properly is composed of building systems, materials, and technologies that are selected and integrated to be mutually supportive as a cohesive "whole" system.

- Meeting performance objectives is a sustained effort that will ensure the owner’s functional and operational requirements are satisfied. It entails assembling a qualified project delivery team, adequately coordinating team member roles and responsibilities, and instituting systematic quality assurance programs.

1.1.2 Aesthetics

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.

- Landscape design that integrates site and building into one concept

- Sequence of access, entry, and use of the building from the viewpoint of both staff and visitors

- Interior finishes that are 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.

- Accent and background colors, with special attention to their psychological effect on people

- Special aesthetic consideration to all building entrance lobby spaces

- Lighting from the view of both visual comfort and aesthetics.

1.1.3 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 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.

- Where feasible and appropriate, expansion space shall be designed for each type of space used in the facility and for parking facilities. Anticipated expansion must be reviewed by representatives of all disciplines on the project. All designs shall address at the concept stage future expansion potential for the facility.

- 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. This does not necessarily mean that extra mechanical system capacity (e.g., boilers, chillers, ductwork) should be designed into the facility at the start, only that additional mechanical room space or infrastructure be considered if appropriate. Wherever feasible, mechanical and other building systems should be designed to operate at the most energy-efficient level required during each stage of the building's operating life—i.e., do not oversize systems but make them flexible enough to respond to foreseeable changes in facility mission and operations, local or regional climate changes, etc.

- 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.

- Ensure that the building automation system (BAS) hardware and software can accommodate future expansions.

1.1.4 Occupant 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:

- Building form has an influence on communication. Whenever possible, personnel that need to communicate should be located in close proximity on the same floor. EPA has a preference for laboratories to be located on one floor for safety and health reasons.

- 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. Solutions that provide for both natural light and office clusters should be strongly considered. Additionally, clustering enclosed offices away from the windows allows a better distribution of natural light; heating, ventilation, and air conditioning (HVAC); and window access to those in workstations.

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

1.1.5 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. Amenities 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.

- 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. When procuring energy consuming products, EPA shall procure either ENERGY STAR® or Federal Energy Management

Program (FEMP)-designated products (EPAct, Section 104). 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.

- EPA shall install bike racks at all new facilities near the building entrance. Buildings should be equally accessible to bicycles and vehicles.

- 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.

Facilities that provide bicycle racks or storage space in proximity to building entrances may be eligible to earn a Leadership in Energy and Environmental Design (LEED-New Construction (NC)® point. Specific requirements are covered in the LEED Reference Guide.

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

1.1.6 Persons with Disabilities

The design and layout of an EPA facility must ensure that the facility is accessible to the physically challenged, in accordance with the Architectural Barriers Act Accessibility Standards (ABAAS) adopted by the GSA in May 2006, 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). Non-adaptable facility features, such as the width of corridors, must be planned to accommodate persons with disabilities from the design phase of facility construction. All adaptable facets of the facility, such as casework or other furnishings or equipment, must be made functional for persons with disabilities. 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 EPA will make the final decision on the interpretation of all codes.

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 all of the users. Casework in all laboratories shall be capable of being modified to meet accessibility requirements at minimum cost. EPA will consider installation of handicapped-accessible equipment in laboratories on a case-by-case basis. When preparing space plans for laboratory modules, the designer shall include the flexibility to convert a percentage of the workstations for use by the disabled at a future date.

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.

1.1.7 Safety, Health, and Environment

EPA facility design and construction must meet all requirements of EPA Facilities Manual, Volume 3, *Safety and Health Requirements* and Volume 4, *Environmental Management Guidelines* and other environmental requirements of this volume. EPA-occupied facilities shall comply with the requirements provided by the EPA, National Fire Protection Association (NFPA), Occupational Safety and Health Administration (OSHA), GSA, Interbational Building Code (IBC), and state and local building and fire prevention codes.

Volume 3 details the safety and occupational health requirements for facilities that are owned, leased, or occupied by EPA.

Similarly, Volume 4 contains detailed information associated with environmental compliance, management, and pollution prevention at facilities owned, leased, or occupied by EPA.

1.1.8 Architectural

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 functions and layouts.

- Zones are composed of two or more similar blocks of spaces.

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.

Aspects of general access to consider 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

- Minimize single-loaded corridors

- Provide clear directional signage for wayfinding, and departmental directories that can be changed easily.

For additional information refer to Chapter 4, *Architectural Requirements*.

1.1.9 Fire Protection

The primary goal for fire protection design shall be life safety, including control of the fire and provision of adequate egress for the occupants. In conjunction with local and EPA requirements, the local fire marshal shall be consulted to address and resolve any special concerns. Attention shall also be provided to the elevator/service elevator design and its function in a firefighting mode. In addition, a fire command center is required inside high-rise buildings.

1.1.10 Physical Security

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. Most facilities have an Employee entrance and Visitor entrance (which in most cases is used as the main entrance). Each major entrance must be designed for incorporation of security equipment as defined in the POR. Security equipment may include x-ray and magnetometer equipment, metal detectors, and card readers.

The building subdivisions and the arrangement of exits, corridors, vestibules, lobbies, and rooms shall conform to requirements of NFPA 101 and shall: (1) allow fast and orderly exit in case of emergency; and (2) 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 station role). Administrative areas shall be in close proximity to the security control station to provide reception function activities.

The exterior spaces on the property shall be adequately secured to eliminate the potential for unauthorized individuals gaining access to the property or facility but configured so egress of building occupants remains unimpeded. Potentially hazardous or accident-prone exterior areas shall be secured by adequate perimeter security.

1.1.11 Equipment Layout and Clearances

Equipment layout and clearances in industrial, storage, and other areas where personnel could be present on a regular basis shall consider the following

- Pedestrian traffic and work flow patterns to ensure personnel are not exposed to hazardous industrial equipment and operations

- Vehicular traffic and work flow patterns to ensure the protection of the equipment and the safety of the equipment and vehicle operators.

1.2 Sustainable Design Requirements

EPA is a recognized leader in energy conservation, pollution prevention, and other sustainable building practices. Consistent with EPA's mission to protect human health and the environment, the architectural and engineering design of EPA facilities shall use strategies and technologies exhibiting respect for, and protection of, the environment. These methods, strategies, and technologies include:

- Reduction in total facility energy and water usage
- Use of recycled-content and biobased construction materials, and construction materials produced with minimal expenditure of energy, water, and waste
- Use of materials and design strategies to achieve optimal indoor environmental quality; and
- Use of renewable energy technologies, where appropriate.

The facility shall be designed to meet the requirements of EPA's pollution prevention policies.

1.2.1 Supporting Regulations, Laws, and Executive Orders

EPA facility designs must meet the requirements of several key laws, regulations, and Executive Orders (EOs). A brief summary of the requirements of each, in chronological order, is provided below in this section. Refer to Appendix A for additional, more detailed explanations.

1.2.1.1 Energy Policy Act of 2005 (EPAct) (August 2005)

The EPAct requirements for federal facilities include, but are not limited to, the following:

- Design all new buildings to achieve energy consumption levels at least 30 percent below American Society of Heating, Refrigeration, and Air Conditioning (ASHRAE) Standard 90.1 (most recent version) requirements (or submit a study and justification to the Office of Management and Budget (OMB) that meeting the 30 percent requirement is not lifecycle cost-effective)

- Procure ENERGY STAR® or Federal Energy Management Program (FEMP)-designated equipment, as applicable, unless it can be demonstrated that this equipment would not be lifecycle cost-effective

- Install advanced metering systems for electricity by October 1, 2012 (refer to Section 7.3.5 regarding criteria for metering of EPA leased facilities)

- Increase use of recovered mineral components in cement and concrete on construction projects.

EPAct also established agency-wide goals for energy consumption reduction and renewable energy use, as discussed in Appendix A.

1.2.1.2 Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (MOU) (February 2006)

The MOU was signed by 21 federal agencies, including EPA. Under this MOU, federal agencies must, where possible, implement a series of five Guiding Principles:

- Employ Integrated Design Principles (use a collaborative team-based design approach, establish project performance goals, employ total building commissioning practices, etc.)
- Optimize Energy Performance (reduce energy cost budget by 30 percent relative to ASHRAE 90.1 (most recent version) for new construction and 20 percent below the fiscal year (FY) 2003 baseline for renovations, install building level utility meters, etc.)[1]
- Protect and Conserve Water (reduce indoor potable water consumption by at least 20 percent relative to the EPAct 1992 baseline, reduce outdoor potable water use by at least 50 percent, employ design and construction strategies to reduce stormwater runoff, etc.
- Enhance Indoor Environmental Quality (conform with applicable ASHRAE Standards for ventilation and thermal comfort, incorporate daylighting into designs, protect indoor air quality during construction activities, etc.)
- Reduce Environmental Impact of Materials (use materials with biobased and/or recycled content, recycle at least 50 percent of construction and demolish debris, eliminate ozone-depleting compounds, etc.)

The Guiding Principles in the MOU were incorporated into Section 2(f) of EO 13423, thus becoming mandatory for <u>all</u> federal agencies.

1.2.1.3 Executive Order 13423 (January 2007)

The EO requirements for federal facilities include, but are not limited to, the following:

- Ensure that, by the end of FY 2015, at least 15 percent of their facilities incorporate the five Guiding Principles expressed in the MOU
- Purchase, where applicable and available, plumbing fixtures and equipment that meet EPA WaterSense™ Program labeling requirements

The EO also requires agencies to achieve agency-wide energy and water intensity reduction targets by the end of FY 2015, and to obtain a certain minimum percentage of their energy from renewable sources installed after January 1, 1999.

1.2.1.4 Energy Independence and Security Act of 2007 (EISA) (December 2007)

The EISA requirements for federal facilities include, but are not limited to, the following:

- Install advanced metering systems for natural gas and/or district steam (where applicable), by October 1, 2016

[1] The MOU references energy cost budget (i.e., the cost a facility would realize from certain energy design decisions). However, EPAct, EISA, and the two Executive Orders require energy consumption intensity reductions, e.g., in British Thermal Units (BTUs) per square foot.

- For certain large new federal construction projects, meet a series of increasing fossil fuel consumption reduction targets, culminating in a 100 percent fossil fuel reduction target for projects begun after FY 2030

- Install only energy-efficient lighting systems (i.e., those that meet ENERGY STAR® certification criteria or, for light emitting diode (LED) lamps, corresponding U.S. Department of Energy (DOE) requirements)

- Where lifecycle cost-effective, provide solar hot water heating systems to meet at least 30 percent of hot water demand at new facilities

- For projects with a total disturbed area footprint greater than 5,000 square feet, use strategies that maintain or restore the predevelopment stormwater hydrology of the property (refer to Appendix I for EPA's applicable guidance document associated with this requirement)

- After December 2010, ensure that all new leases for space executed by federal agencies are in ENERGY STAR-certified buildings

- Employ the most energy-efficient designs, systems, equipment, and controls (so long as they are also lifecycle cost-effective) for large capital energy investments such as equipment replacement, space renovations or expansions, etc. (does not apply to new construction projects). Refer to Appendix G for EPA's procedure for complyng with this requirement.

EISA also increased the required agency-wide energy intensity reductions to align with those specified in EO 13423.

1.2.1.5 Executive Order 13514 (October 2009)

The most significant requirements of this EO address the issue of global climate change; for example, the EO requires federal agencies to develop greenhouse gas (GHG) inventories and set agency-wide GHG reduction targets. Many of the specific requirements of the EO that directly affect federal facilities are linked to building design and construction. They include, but are not limited to, the following:

- Similar to EPAct, procure ENERGY STAR or FEMP-designated equipment, as applicable, unless the agency operating the facility demonstrates that this equipment would not be lifecycle cost-effective

- As introduced in the MOU and §2(f) of EO 13423, meet the five Guiding Principles in at least 15 percent of the agency's buildings by the end of FY 2015 and make annual progress toward eventual 100 percent conformance with the Guiding Principles throughout each agency's entire building inventory[2]

- Pursue innovative strategies to minimize consumption of energy, water, and materials, where feasible and lifecycle cost-effective, such as highly reflective and vegetated roofs

- Ensure that all new projects that enter the planning stage (and subsequent design and construction) after FY 2020 are designed to be net zero energy buildings (NZEBs) by 2030.

[2] This requirement applies for all federally-owned and federally-leased buildings above 5,000 square feet (total).

- While siting new facilities (new construction and leases), consider sites that are "pedestrian friendly, near existing employment centers, accessible to public transit, and that emphasize existing central cities and, in rural communities, existing or planned town centers"

- Recycle/divert from disposal at least 50 percent of construction and demolition materials and debris by the end of FY 2015

This EO also increased the agency-wide water use reduction targets. Federal agencies will now be required to reduce total water consumption by two percent annually (or total of 26 percent by the end of FY2020), relative to their FY 2007 baseline consumption. The EO specifically calls out certain strategies that should be evaluated, including water-efficient and low-flow plumbing fixtures and efficient cooling towers. In addition, water used for industrial, landscaping, and/or agricultural uses must be reduced by two percent annually or 20 percent by the end of FY 2020, relative to the FY 2010 baseline.

1.2.1.6 EPA Sustainable Buildings Policies that Exceed the Existing Federal Requirements

EPA has taken a leadership position among federal agencies, and has adopted certain additional goals and objectives for high-performance, sustainable buildings, as follows:

- Strive for Leadership in Energy and Environmental Design (LEED®) Gold for New Construction (LEED-NC Gold) on all new construction and major renovation projects greater than 5,000 total square feet, but achieve a minimum rating of LEED-NC Silver

- Recycle a minimum of 75 percent of construction and demolition debris for projects greater than 20,000 square feet

- Through a combination of on-site renewable energy projects and purchase of renewable energy credits (RECs), ensure that 100 percent of the electricity used by EPA facilities is generated by renewable energy sources (i.e., not via fossil fuels combustion)

- Use low-flow fixtures that meet or exceed the WaterSense standards, where applicable, for example – a maxmimum flow of 0.5 gallons per minute (gpm) for lavatory faucet aerators (additional low-flow fixture requirements and standards are described in Section 6.10.2 of this Manual

1.3 Laboratory Zone Design Requirements

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. Window exposure for daylighting both offices and laboratory spaces should be an important consideration, so long as heat loss or gain through the windows is not excessive (consider other means of reducing heat loss such as double- or triple-glazings, where practicable).

1.3.1 Laboratory Modules

Laboratories are an important focus area for sustainability efforts because they use up to five to 10 times more energy than the average office building and significantly more water. For this reason, they should be separate and distinct from regular office and support space. 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: (1) disturbing adjacent spaces; or (2) altering (or forcing shutdown of) central building utility systems. Specific requirements for laboratory modules are as follows:

- 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 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, and 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, where possible, in spaces outside the laboratory zones. (Servicing building systems components inside the laboratories can be disruptive and difficult because of the amount of scientific equipment that must be protected.) Wherever systems components must be located above ceilings (e.g., ventilation system terminal boxes), 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.

1.3.2 Support Block

Laboratory support space shall suit the needs of the specific laboratory. In some cases, a service corridor is used for laboratory support, while in other 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 between laboratory support spaces and individual laboratories and zones, with an emphasis on the efficiency of the travel path of personnel, tasks, and material within a particular zone and between zones.

1.3.3 Technical Space

Research support personnel (i.e., technicians, post-doctoral employees, laboratory assistants) should be provided with work space outside of the laboratory room, which reflects the mixed usage of laboratory and non-laboratory space inherent with their typical duties. 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 located so 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. In some instances, a physical separation or barrier may be required between the work space and the laboratory bench.

1.4 Support Zone Design Requirements

1.4.1 Administrative-with-Support Zones

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: conference rooms, storage areas, copier areas, computer and printer areas, and coffee/vending areas. Microwaves and other cooking appliances shall be enclosed and exhausted directly to the outdoors to maintain indoor air quality (IAQ). Copier areas shall also be enclosed and directly exhausted to the outside.

Adequate space near the copiers and printers is needed for the proper placement of recycling bins for: (1) mixed office paper, (2) newspapers, (3) dry-cell batteries, (4) toner cartridges, and (5) “technotrash.” Pantries should include space for recycling bins for: (1) bottle and cans, (2) plastic bags, and (3) #3-#7 plastic items. Office buildings should allocate a minimum area of 50 square feet plus an additional 4 square feet per 1,000 gross square feet (GSF) for recyclables storage. Special care is required to design floor loading, fire ratings, and increased fire sprinkler densities for film and paper storage areas. A preaction fire sprinkler system shall be considered when conducting the fire protection analysis for these areas.

1.4.2 Building Support Zones

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 facility. The truck turning radius to loading facilities should be appropriate to the truck sizes anticipated. The loading dock might include a leveling device for accommodating different-sized trucks. A covered loading/unloading area is desirable. Where appropriate, the loading dock area shall contain video monitoring apparatus for security purposes. Additional issues to resolve are as follows:

- Explosive wall or roof area size
- The flow of mail delivery into the facility through the loading dock and associated security procedures
- Access for emergency vehicles and ramps
- Truck parameters (dock height, leveler requirements)
- Security requirements
- Concrete paving for loading dock area
- Dumpster and compactor requirements
- Area for waste stream separation and recycling.

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

1.5 Other Specialized Zone Design Requirements

Other specialized zones include restrooms, janitorial closets/custodian space, shop facilities, libraries, chemical and general storage, food service areas, and outside research facilities. Refer to Section 4.12, *Building Support Zones* for additional information on these areas.

1.5.1 Restrooms

Men's and women's restrooms in the fitness center and bike storage areas 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 the applicable ABAAS requirements. All sanitation finishes shall be non-permeable, non-corrosive, and easily maintainable. Restrooms shall be equipped with exhaust ventilation to the outside.

1.5.2 Janitor Closets/Custodian 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 outside 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.

1.5.3 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.

1.5.4 Libraries

On-site libraries 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.

1.5.5 Chemical Storage

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

1.5.6 General Storage

General storage is usually required on every floor. Issues to resolve:

- Ensure good access to the service elevator(s)
- Size rooms with freezers or other bulky equipment relative to equipment dimensions and layout
- Check corridor and elevator dimensions for movement of equipment typically stored
- Ensure that space is provided to collect, store, and compress corrugated cardboard for recycling. This may include space for bins, compactors, and/or balers.

1.5.7 Food Service

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

- Quantity of seating required
- Type of food service to be provided
- Secondary uses of food service spaces (if any)

- Placement of separate recycling bins for collecting: (1) newspaper, (2) commingled bottles and cans, and (3) other, future segregated wastes as required (e.g., compostable organic wastes, plastic bags, and other assorted #3-#7 plastics).

1.5.8 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.

1.6 Design Process

EPA is a strong proponent of integrated design. Integrated design requires that all stakeholders evaluate project objectives and building materials, systems, and assemblies from many different perspectives in order to leverage interdependencies. This approach is an improvement from the typical planning and design process of relying on the expertise of specialists working in isolation from one another and from rigid sets of requirements. By achieving synergies between disciplines and between technologies, EPA can produce more efficient and cost-effective buildings that better comply with environmental and safety requirements and promote worker productivity and satisfaction.

1.6.1 Pre-Design Process

The pre-design process for EPA facilities, including space acquisition and planning requirements, is generally discussed in Volume 1*, Space Planning and Acquisition Guidelines*. 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 areas, number of laboratories/special spaces, offices, location of site, acreage, and other characteristics

- An environmental design intent document, which identifies the sustainable design goals and initial concepts; this document should evaluate the design criteria against the following sources:

  – Applicable LEED credits

  – The Guiding Principles found in the *Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding* (MOU)*.* Section 2(f) of EO 13423 mandates that all new construction and major renovation projects at Federal facilities comply with the Guiding Principles. (EO 13423 was subsequently codified into law by Section 748 of the Omnibus Appropriations Act of 2009)

– EO 13514 requirements, as discussed previously in Section 1.2.1, such as siting criteria, compliance with the Guiding Principles, and (for projects begun after FY 2020) how the design will promote attainment of NZEB status

- 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* (the room data sheets must indicate specific room or laboratory requirements and identify appropriate installed equipment)

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.

The EPA project manager, with assistance from the EPAis required to complete a GreenCheck form for each qualifying project. The GreenCheck form provides a current list of the sustainability requirements that a project must achieve.

1.6.2 Design Submittals

The Project Architect/Engineer (A/E) shall submit required construction drawings, specifications, cost estimates, energy simulations, and design analyses/calculations to the EPA's Facilities Management and Services Division (FMSD) at interim stages of development. Not all projects will require submission at each of the stages indicated below. EPA does, however, reserve the right to still require specific submittals from stages not specifically required (i.e. Code Analysis, Life Safety Plan, etc.). If submittals are found to be unacceptable at any stage, the A/E shall revise and resubmit them at no additional cost to EPA. It is expected that the design submittals will reflect integrated design and sustainable practices, since EPA has gone through a process whereby it has entered into national contracts with A/E firms that have strong green building qualifications.

Within 30 days following the initial design charrette, the project A/E shall submit a Basis of Design (BOD) document that addresses all requirements presented in the POR and/or discussed during the design charrette.

EPA shall separately contract for a Commissioning Agent at the time a design contract is awarded. The selected Commissioning Agent shall be involved in all design reviews beginning at the 15 percent submittal. EPA's commissioning guidelines are contained in Appendix E of this Manual.

To earn LEED NC 2009 certification, a project must meet the requirements of LEED Prerequisite Energy and Atmosphere (EA) Prerequiste 1, *Fundamental Commissioning of Building Energy Systems.* The Prequisite requires that the project Owner (i.e., EPA) prepare an Owner's Project Requirements (OPR) and that the designer prepare, in response to the OPR, a Basis of Design (BOD) document. Specific requirements can be found in the LEED Reference Guide. (An OPR is essentially the same type of document as an EPA POR).

1.6.3 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 percent submittal ensures that the A/E demonstrate an understanding of the scope of the project and will adhere to project criteria, formats, and conventions. At this stage, the A/E will submit, for example:

- Updated BOD, where applicable
- 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 treatments, and utilities
- Environmental design plan, including energy goals, water consumption strategies, renewable energy opportunities, stormwater management approaches, materials selection, indoor air quality considerations, and strategy for achieving LEED Certification and (once operational) LEED Existing Buildings: Operations and Maintenance® (EB:O&M) certifications (where required)
- Cost estimate reflecting the cost of the intended project and the cost of alternate schemes/solutions presented, including the cost for providing expansion contingency
- Preliminary analysis of LEED Certification potential, with checklist identifying the points to be sought and the strategies and steps necessary to achieve them.
- Code analysis, identifying all applicable codes and key criteria that will affect the design.

1.6.4 35 Percent Submittal

The 35 percent 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:

- Updated BOD, where applicable
- Site development plans delineating all buildings in the area, proposed parking locations, roads, sidewalks, curbing, fencing, landscaping, stormwater management system, 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

- Energy model baseline simulations and preliminary calculations compared to the relevant energy reduction requirements:
  - 30 percent or more below the ASHRAE 90.1-2007 (or most recent version) energy consumption baseline for new construction, or
  - Minimum 20 percent below the FY 2003 facility energy baseline for major renovations.
- Updated analysis of LEED Certification potential, with accompanying checklist
- Life safety plans showing fire subdivisions, fire separation ratings throughout the building, occupant load calculations, and exit capacity calculations (refer to Chapter 9, *Fire Protection* for additional information)
- Preliminary furniture layouts for conference rooms, libraries, and similar spaces
- Mechanical plans delineating proposed layout of systems, locations and preliminary arrangements of all major items of mechanical equipment
- Basic outline of control system requirements (materials, methods, and sequence of operation). Preliminary one-line or ladder diagrams for the HVAC system and HVAC control system will be submitted as part of the electrical package (see electrical plans bullet below)
- Plumbing plans showing proposed fixture locations and basic riser diagrams
- Electrical plans showing proposed electrical service and distribution array (preliminary one-line or ladder diagrams), lighting fixture patterns, and receptacle locations
- Reflected ceiling plans
- Security plan describing the methods, procedures and measures that will be used to maintain site security
- Preliminary List of Materials containing recycled content and percent of pre- and post-recycled content, on a weight or cost basis. The formula for calculating Recycled Content Value for each material on a cost basis is as follows:

  > Recycled Content Value for a specific material ($) = (% post-consumer recycled content (by weight) x material cost) + 0.5 x (% pre-consumer recycled content (by weight) x material cost),
  >
  > *then,*
  >
  > Sum the Recycled Content Value for all materials and divide by the Total Materials Cost.
  >
  > Refer to the LEED Reference Guide for more detailed instructions on calculations of recycled content.

  At a minimum, the 10 most abundant materials used in the project (by weight or cost, as applicable) should be included in the Preliminary List of Materials.

- 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.

1.6.5 60 Percent Submittal

The 60 percent submittal includes contract documents and supporting materials that clearly show the development of the project at the 60 percent 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 percent submittal shall include, for example:

- Updated BOD, where applicable

- 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

- Developed roof plan and exterior elevations

- Revised reflected ceiling plan

- Developed schedule of finishes

- Updated LEED checklist, including preliminary calculations for points sought

- Updated Energy Model with updated energy use calculations, presented in BTUs of each fuel type, total BTUs, and energy cost budget (ECB) format, with an explicit statement of fuel costs used to calculate the ECB

- Preliminary domestic water use calculations compared to the 20 percent-less-than-facility's baseline, calculated after meeting EPAct 1992 fixture performance requirement

- Preliminary site stormwater calculations determining the rainfall intensity (in inches) and runoff associated with the 95th percentile storm, consistent with EPA's *Section 438 Technical Guidance*, EPA 841-B-09-001, December 2009. In addition, runoff quantities that exceed the 95th percentile storm shall be provided where required by local flood control ordinances and codes (and in conformance with those ordinances/codes) (the Technical Guidance is available at www.epa.gov/owow/nps/lid/section438

- Completed fire protection/life safety plans including fire sprinkler/standpipe calculations, fire alarm drawings, and a detailed description of the fire alarm system (refer to Chapter 9, *Fire Protection* for additional information) Detailed calculations and description of any fire suppression or smoke control/exhaust system and its controls shall also be provided.

- Detailed calculations 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, sensors [type, accuracy, precision], and control valves). This section shall also include a description of, and vendor specifications for, the Building Automation and Control System (BAS) (refer to Chapter 8 of these Guidelines for detailed requirements of the BAS). The control system descriptions must also discuss air inflow and exhaust balancing, system response time, turn-down capacity of major equipment and systems, including (1) ventilation air ducts and dampers and (2) hydronic system piping and associated valves)

- 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 panel boards (including short circuit and voltage drop calculations), electrical metering, electrical schedule and fire alarm system (including battery calculations).

- GreenCheck submittal titled "Project name – 60 percent design stage"

- Detailed cost estimate using quantity take-offs and unit prices.

The A/E firm shall coordinate the submission of the 60 percent submittal with the Draft Systems Commissioning Plan developed by EPA's independent commissioning agent for the project.

1.6.6 95 Percent Submittal

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

- Contract drawings and specifications that are 100 percent complete for all disciplines (architectural, structural, mechanical, electrical, fire protection, fire alarm)

- 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-time items, and/or items that because of their uniqueness, rareness, and/or 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 internal funding procedures
- Draft LEED submittal to the LEED Online® system, including the overall point total checklist and all credit-by-credit submittals and required information (except that to be collected during construction)
- GreenCheck submittal titled “Project name – 95% design stage”
- Recycling Plan for construction phase.

1.6.7 100 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 manufacturers’ catalog cuts and published data of major items specified and used as basis of the design.

1.7 Construction

1.7.1 Recycling Plan for Construction Materials

Planning and on-site management can result in the reduction of construction waste generated, and the diversion of construction and demolition (C/D) 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. The A/E shall include in the specifications and in the contract documents the following requirements:

- For projects less than 5,000 GSF, a minimum of 50 percent of construction waste shall be recycled, and
- For projects greater than or equal to 5,000 GSF, a minimum of 75 percent of construction waste shall be recycled.

The above percentages are by weight, not by volume.

The contractor shall recycle as much material as possible throughout all project phases, to meet or exceed the above targets. To accomplish this, the contractor shall:

- Submit a Construction Waste Management Plan detailing how the waste stream will be separated and managed
- Provide on-site 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.

Refer to Chapter 11, *Construction-Related Issues* for additional information on C/D waste recycling.

1.7.2 Indoor Air Quality Requirements During Construction

EPA recognizes that practices during the construction process can further the project's environmental goals (or compromise them). Stored and installed materials and equipment must be protected during the construction period from damage, dirt, chemicals, and moisture. To ensure acceptable indoor air quality at occupancy, it is important that pollutants do not lodge in the building's air handling systems, such that the system can circulate them throughout the finished space. The A/E shall include in the specifications and in the contract documents the requirement for the contractor to provide a Construction Indoor Air Quality (IAQ) Management Plan that meets all applicable guidance (EPA, OSHA, Sheet Metal and Air Conditioning Contractors' National Association [SMACNA], etc.). Refer to Chapter 11, *Construction-Related Issues* for additional information on IAQ during construction. Section 11.2.2 addresses moisture control during construction to prevent mold growth, including the requirement that all (1) absorptive construction materials be protected from rain while in storage, (2) damp materials be dried out prior to installation, and (3) drywall and other indoor materials not be installed until the space is enclosed.

1.7.3 Construction Management

Construction management is a critical component of a new construction or major renovation project. To ensure that construction activities are conducted in accordance with applicable plans and specifications, the construction contractor shall:

- Furnish, for the Government's review and approval, the Contractor Quality Control (CQC) Plan that will implement the requirements of the quality control (QC) system. 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

- Establish a program for inspection of activities affecting quality that covers both on-site and off-site construction operations. At a minimum, inspections must be performed prior to beginning any work on any definable feature of work, as soon as a representative portion of a particular feature of work has been accomplished, daily following the initial inspection of the accomplished work, and at completion of a particular feature of work. Require submittal of daily and weekly construction reports, which include a description of the work performed, any inspection findings, and all QC testing results

- Conduct weekly project management meetings to review project status and resolve non-conformance issues

- Prior to acceptance of the work, participate with EPA in a site-walkover/completion inspection and develop a punch list of items that do not conform to the approved plans and specifications. Conduct a second completion inspection after punch list items have been completed to verify conformance

- Establish a test program to ensure that all required materials testing procedures are properly identified, planned, documented, and performed under controlled and suitable environmental conditions. Specific materials testing requirements for concrete are contained in Chapter 5, Section 5.3.11 of this Manual. Quality assurance of other materials and assemblies generally will be through use of properly qualified and licensed personnel, routine and thorough inspection of work (including non-destructive testing methods), and conformance with applicable industry codes and standards. Any additional materials testing outside that described above shall be specified separately by the EPA project manager

- Conduct regular inspections of the erosion and sediment controls (during construction) and stormwater management system (post-construction) as required by the specifications and the facility's stormwater pollution prevention plan.

The construction contractor shall permit EPA's selected independent commissioning agent to conduct scheduled or unscheduled monitoring and inspections during construction activities. Any identified issues that cannot be resolved shall be brought to the attention of the EPA project manager for evaluation and resolution.

1.7.4 LEED Design

LEED-NC addresses design and construction activities for both new buildings and major renovations of existing buildings. To obtain LEED Certification, the A/E shall:

- Include in the specifications and the construction contract a requirement that the contractor identify a LEED Coordinator who is responsible for the collection and submittal of LEED-related documentation in a timely manner during construction (documentation of recycled materials content for construction materials used, bills of lading wastes recycled off site, etc.). The specifications and construction contract shall indicate that payment to the contractor will be linked to prompt submittal of LEED documentation to the A/E and/or LEED consultant

- Register the project on the USGBC Web site (www.usgbc.org) in the LEED section, under "Register Your Project." Projects will need to comply with the LEED-NC version that is current at the time of registration

- Retain a LEED Accredited Professional (LEED AP) to provide guidance on completing the LEED-NC application

- Use LEED-Online to characterize which LEED Credits are applicable to the project and generate a preliminary estimate of LEED credits and total point score

- Submit a draft LEED certification application to the USGBC's LEED Online system, including the overall point total checklist and all credit-by-credit submittals and required information (except that to be collected during construction)

- At the end of the construction phase, submit a final LEED certification application to USGBC using the LEED-Online system. (LEED Credits designated as "design phase credits" may be submitted at the conclusion of the design phase for review by USGBC. However, verification that the design elements were implemented as planned must be submitted after completion of construction).

1.7.5 Testing Procedures

The Contractor shall perform QC testing in accordance with written procedures in the CQC Plan. The CQC Plan provides the control, verification, and acceptance testing procedures for each specific test including the test name, specification paragraph requiring test, feature of work to be tested, and person responsible for each test. The test procedures shall incorporate or reference the requirements as contained in the contract specifications, codes, and industry or nationally recognized standards including, for example:

- American Concrete Institute (ACI)

- American National Standards Institute (ANSI)

- ASHRAE
- American Society of Mechanical Engineers (ASME)
- American Society of Testing and Materials (ASTM)
- American Welding Society (AWS)
- International Electrical Testing Association (NETA)
- NFPA
- Portland Cement Association (PCA)
- National Electrical Manufacturers Association (NEMA).

The test procedures shall be reviewed and accepted by the CM prior to their implementation. The contractor shall record the QC test results in the daily test reports and submit the QC test results to the CM prior to the start of the next day's work period. The CM will be responsible for reviewing the test reports on a daily basis, identifying any non-conforming test results and discussing potential corrective actions for non-conforming results with the contractor.

Quality assurance (QA) testing shall be conducted by the CM for the verification of the adequacy and effectiveness of the contractor's QC testing. QA testing is independent of the QC testing performed by the contractor and shall be performed on a pre-established schedule or as directed by the CM. The typical test frequency is one (1) QA test for every 10 to 15 of the construction contractor's QC tests. More frequent testing during initial startup may be necessary to verify the process is under control and complies with the specifications. In lieu of performing independent tests, the CM may either witness the QC testing or conduct tests on samples from the QC testing (e.g., "split" samples). When QA and QC test results have wide variances or are not comparable, additional testing may be required to validate the results.

1.7.6 Construction Submittals

Construction submittals are required throughout the construction process. Submittals required prior to the commencement of construction activities include, for example:

- Work Plan, including the roles and responsibilities of the team members
- Construction stormwater Pollution Prevention Plan (SWP3) and/or Erosion and Sedimentation Control Plan (ESCP), as required by local regulations or ordinances
- CQC Plan including identification of personnel, procedures, controls, instructions, tests, records, and forms to be used
- Emergency Response Plan
- Spill Prevention, Countermeasure and Control (SPCC) Plan, where applicable.

Submittals required during construction include, for example:

- Daily/weekly construction reports
- Minutes from weekly construction progress meetings

- Inspection and testing report forms
- Interim progress reports
- Hot work and confined space entry permits.

Submittal required following the completion of construction include, for example:

- As-built drawings
- Operations and maintenance manuals (i.e., for HVAC and electrical systems and equipment)

The Commissioning Report will be completed by the Independent Commissioning Agent retained by EPA (refer to Section 1.8 below). The construction contractor shall coordinate submittals of project documents such as inspection, testing, and repair/modification reports with the Commissioning Report, as applicable.

1.8 Commissioning

Commissioning is a quality-focused process for enhancing the delivery of a project. The process focuses on verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements. Systems to be considered for commissioning include the building envelope (e.g., roofing, windows and doors), plumbing systems, HVAC system, BAS controls, electrical systems, fire protection and life safety systems, renewable energy systems, and the security system. In addition to uncovering deficiencies in design or installation using peer review and field verification, effectively commissioned buildings and systems also accomplish higher energy efficiency, environmental health, and occupant safety. EPA requires commissioning for all new building construction greater than 20,000 square feet. EPA's Commissioning Guidelines are contained in Appendix E of this volume.

All LEED-NC 2009 certified buildings must achieve the fundamental level of commissioning defined in the applicable LEED prerequisite. There is also an Enhanced Commissioning Credit, under which EPA facilities can earn points for a more extensive and rigorous commissioning program. EPA has prepared a Commissioning Guide to be used at all its facilities. Following the provisions of the Commissioning Guide and the applicable provisions of this Manual, should ensure that EPA new construction and renovation projects fulfill the prerequisite and, in almost all cases, be eligible for the two points under the Enhanced Commissioning credit.

The Commissioning Agent shall be an independent entity from the A/E. Construction specifications shall include language that the construction contractor will coordinate, cooperate, and address issues found by the independent commissioning agent.

1.9 Life Cycle Cost Analysis

1.9.1 Overview

Life cycle cost analysis (LCCA) is an economic method of project evaluation in which all costs arising from owning, operating, maintaining, and ultimately disposing of a project are considered to be potentially important to that decision. It is particularly suitable for the evaluation of building design alternatives that satisfy a required level of building performance, but that may have different initial investment costs; different operating, maintenance, and repair (OMR) costs; and possibly different useful lives. LCCA provides a significantly better assessment of the long-term cost effectiveness of a project than alternative economic methods that focus only on first costs or on operating-related costs in the short run; thus it has been endorsed by the Government for all major capital projects. LCCA should be completed during the Design Development Phase of the project.

Handbook 135, *Life Cycle Costing Manual for the Federal Energy Management Program/ National Institute of Standards and Technology* (1995 or most recent version) provides guidance to federal agencies for using LCCA to evaluate capital investment projects which reduce future operating and maintenance (O&M) costs of federal facilities. It expands on the life cycle cost methods and criteria contained in the FEMP rules published in 10 CFR 436, Subpart A, which applies to all federal agencies. These rules are to be followed, unless specifically exempted, in evaluating the cost-effectiveness of all new construction or major building renovation projects, potential energy and water conservation projects, and renewable energy projects. As a companion product, the National Institute of Standards and Technology (NIST) has also established the Building Life Cycle Cost (BLCC) computer program to perform LCCA. For projects not related to energy or water, OMB Circular A-94 (1992 or most recent version) provides the necessary methodology.

1.9.2 Incorporation of Energy and Water Use Evaluations Recommendations

Federal agencies, EPA included, are required to conduct annually a comprehensive energy and water use evaluation for at least 25 percent of their facilities, ensuring that each facility is evaluated every four years. If a finding from one of these evaluations indicates that an energy or water efficiency measure may be beneficial, then an LCCA must be performed (EISA, Section 432). The results of any applicable energy and water use evaluations will be provided to the A/E, and the A/E shall ensure that any designs reflect any recommended changes or improvements specified by the energy and/or water use evaluations.

1.9.3 Equipment Analysis Requirements

Federal agencies, including EPA, are required to ensure that any capital energy using equipment investment uses the most energy-efficient designs, systems, equipment, and controls that are life cycle cost effective (EISA, Section 434 provided in Appendix G). This requirement applies to projects in an existing EPA-occupied building that are not a major renovation but involve replacement of existing equipment/systems (such as heating and cooling systems, including boilers, chillers, etc.), or involves renovation, rehabilitation, expansion, or remodeling of existing space. EPA is required to use ENERGY STAR or FEMP-designated equipment where feasible and cost-effective according to a LCCA (EPAct 2005, Section 104).

1.9.4 Energy Consumption and Renewable Energy Use Analysis Requirements for New Construction or Major Renovations

EPA new construction projects over 5,000 square feet are required to achieve 30 percent or more below the ASHRAE 90.1-2007 (or most recent version) energy consumption baseline for new construction. For projects that cannot achieve these goals, an LCCA to support the exemption must be prepared and submitted to OMB. Construction projects that are major renovations of existing facilities must achieve 20 percent or more below the facility's FY 2003 energy consumption baseline, provided it is life cycle cost-effective (no submittal to OMB is required, although the LCCA should follow applicable Government regulations and guidance, e.g., 10 CFR 436, Subpart A, OMB Circular A-94).New EPA facilities or major renovations of existing facilities are required to meet at least 30 percent of their domestic (i.e., restrooms, kitchens) hot water demand from solar hot water heaters provided that it is life-cycle cost effective (EISA, Section 523). If the new construction or major renovation will not meet this requirement, then a LCCA must be performed to justify the exemption to OMB.

2. PLANNING AND SITING

The purpose of this chapter is to present guidance and criteria for project Architect/Engineers (A/Es) when planning and siting new EPA facilities or renovating existing facilities.

The appropriate EPA authority (e.g., Regional Office, Program Office, or Headquarters) and the EPA Project A/E (assigned by the EPA Architecture, Engineering, and Asset Management Branch [AEAMB]) shall be integral in the planning and siting of EPA facilities. In addition, it is expected that one or more A/E contractors (i.e., an engineering design and/or construction firm) will assist EPA' selected Project A/E. It is beneficial to involve construction contractors early on in the process to ensure that project site development is technically feasible and cost effective.

With respect to planning and siting EPA facilities, EPA strongly encourages reducing or eliminating potential environmental impacts and, therefore promotes the use of "green" design and planning principles. "Green" design and planning principles are inherent in EPA's mission and also ensure compliance with Executive Orders (EO) 13423 and 13514, the Energy Policy Acts of 1992 and 2005 (EPAct) and the Energy Independence and Security Act of 2007 (EISA).

2.1 Siting Requirements

2.1.1 General Siting Considerations

It is necessary to assess, analyze, and address all site-related issues outlined below and to comply with the requirements of EO 13514 and the associated *Sustainable Locations for Federal Facilities* Implementing Instructions*, and* (where applicable) Chapter 2, Site Planning and Landscape Design of the U.S. General Services Administration (GSA) publication PBS-P100, *Facilities Standards for the Public Building Service* (PBS) (2005 or most recent version). The following issues are to be studied in assessing the impact of a project on a site:

- Existing site features and vegetation
- On-site capacities of present and future utilities
- Existing buildings (including any need for temporary facilities and services to these buildings)
- Existing site utilities (including any need for utility relocation and shutdown)
- Existing traffic patterns for all vehicles, including emergency and service vehicles
- Stormwater run-off, including the ability to maintain or restore the pre-development hydrology, based on flow, rate volume, temperature, and duration OR retain at least the runoff from the 95th percentile storm on site
- Wastewater discharge (including acid wastewater)
- Availability and proximity of public transportation
- Need for traffic phasing and control-plan requirements
- Existing parking structures and surface parking
- Energy usage and exhaust discharge
- Extension or expansion of site utility services
- Need for an environmental analysis, under the National Environmental Policy Act (NEPA).

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
- Indigenous plant and animal species
- Availability of existing utility services
- Building setback requirements
- Availability of existing road systems and public transportation
- Proximity to public transportation
- "Pedestrian-friendly" sites
- 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
- Regional and agency climate change adaptation planning.

In addition, the following issues must be taken into account in determining whether the proposed development site is appropriate and compatible with its natural environment and surrounding community:

- Preserving surrounding neighborhoods and communities

- 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 the 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.

2.1.2 Land Area

When planning and siting EPA facilities, the land and adjacent area shall be considered during site selection. In general, EPA encourages building on previously developed land, rather than on undeveloped property. If brownfield sites are considered, remedial actions must be identified and selected per EPA guidelines prior to construction (*implementation may occur before and/or during construction, as appropriate. For example, areas of contaminated soil are often removed during foundation investigations or installation*).

For new EPA facilities, the following land types should be avoided:

This section adequately addresses the siting restrictions in LEED-NC 2009 Sustainable Sites Credit 1, with the exception of developing on public parkland. Therefore, any EPA project that complies with the criteria in this section <u>and</u> is not sited on public parkland can earn one LEED point.

- Prime farmland as defined by the U.S. Department of Agriculture (USDA) in Title 7 Code of Federal Regulations (CFR), Section 657.5 (7 CFR 657.5)
- Previously undeveloped land whose elevation is lower than 5 feet above the elevation of the 100-year flood as defined by the Federal Emergency Management Agency (FEMA)
- Land that is specifically identified as habitat for any species on Federal or State threatened or endangered lists
- Within 100 feet of any wetlands as defined by 40 CFR 230-233 and 40 CFR 22, and/or isolated wetlands or areas of special concern identified by state or local regulations
- Previously undeveloped land that is within 50 feet of a water body, defined as seas, lakes, rivers, streams, and tributaries that support or could support fish, recreation, or industrial use, consistent with the terminology of the Clean Water Act (CWA).

2.1.3 Zoning and Other Land Use Controls

During the planning process and development of associated environmental documentation for new construction and major renovation projects, all applicable local land development zoning requirements of the state and/or local government should be considered. Even though EPA is exempt from local zoning and building code requirements (except in coastal zone areas), EPA's policy is to follow local zoning requirements, wherever possible. These include, but are not limited to, laws relating to landscaping, open space, density limitations, building setbacks, building height, buffer requirements, historic preservation, noise pollution, aesthetic qualities, critical habitats, and other development guidelines or requirements. Applicable zoning guidelines of university campuses, research parks, or military bases shall also be considered and followed (e.g., if/where an EPA facility is part of a greater planned campus). When zoning codes conflict, the most stringent standard shall govern. Information on applicable codes must be submitted as part of planning and design documents, as discussed below.

Under the Sustainable Sites category of LEED-NC 2009, points may be earned for various site attributes. Credits range from brownfields redevelopment to public transportation proximity to availability of open space (for biodiversity) to development density and community connectivity. These criteria may be utilized when attempting to find a suitable new site or comparing candidate sites. Existing sites may also have some of these attributes.

Laboratory facilities shall be located in areas where local zoning permits; however, facilities should be no less than ¼ 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. The A/E design contractor must fully investigate and address local zoning criteria to ensure zoning compliance for EPA facilities. A brief overview of local zoning and land development codes and their impact on site development should be given for the proposed project in planning and design documents. The potential transmission of noise above background levels also is a key consideration when siting new laboratories or undertaking major renovations of laboratories that would significantly increase existing noise levels.

Consistent with EO 13514, emphasis should be given to locating facilities in existing central city areas, or, in rural communities, existing or planned town centers. However, it must be recognized that certain EPA operations such as laboratories must have adequate buffer zones between operations that handle hazardous materials or generate air emissions and adjacent and nearby properties. Types of zoning and land use in the facility vicinity will naturally strongly influence the required buffer zone/area (e.g., industrial parks versus facilities in proximity to residential and commercial properties). As mentioned in the previous paragraph, air emissions modeling and ground level concentrations, as well as prevailing winds and other local climate conditions, will be critical considerations for siting laboratories. Additional guidance document(s) are forthcoming, which will describe in greater detail how Federal operations should locate their facilities to best conform with the intent of EO 13514.

Any proposed deviations from such codes and laws are to be documented, fully justified, and brought to the attention of the Project A/E. Local regulations must be followed with respect to systems that have a direct impact on off-site terrain or utility systems (such as stormwater run-off, erosion control, sanitary sewers and storm drains, water supply, gas, electrical power and communications, emergency vehicle access, and roads and bridges).

With respect to parking spaces, the design requirements given in the project’s Program of Requirements (POR) take precedence over zoning ordinances. The A/E design contractor and the EPA Project A/E shall consider strategies to address and resolve any zoning concerns or conflicts.

2.1.4 Existing Building(s) Size

The reuse, renovation, or upgrade of existing, previously occupied buildings is encouraged, where practicable. The use of existing buildings provides several advantages. “Green field” properties (usually in the suburban or exurban areas) can be preserved for agricultural use or as open land for ecological habitats and human recreation. A large amount of energy (and associated carbon and other pollution emissions) associated with manufacturing much of the new building materials is consumed. The project also may be completed more quickly.

Projects that maintain a high percentage of the structural elements of an existing building (and/or) certain permitted types of non-structural elements can earn points under LEED-NC 2009. Consult the LEED Reference Guide for additional detail on the criteria that must be fulfilled under these Credits and possible point totals (these range from one to four points, depending on percentage reuse of certain building components, e.g., floors, interior and exterior walls, roof, doors, floor coverings).

2.1.5 Footprint and Orientation

The use of site design to assist with energy conservation and sustainability goals is encouraged when planning and siting EPA facilities. Refer to the U.S. Department of Energy (DOE) publication, *Greening Federal Facilities* (2001) for design strategies and additional information.

The proposed facility footprint should minimize impacts to the environment. Existing site features should be generally preserved and be used as a starting point for overall site design. The total impervious footprint of the facility should be minimized. Where feasible, the building’s solar orientation shall be designed to maximize energy efficiency. The orientation of the building can be designed to increase heat gain in the winter and reduce heat gain in the summer. In general, rectangular buildings should be oriented with the long axis running east-west. In this configuration, east and west walls receive less direct sun in the summer, reducing unwanted heat gain. The same configuration works well for buildings in cold climates where passive solar heat gain on the south side during the winter is desired.

2.1.6 Transportation Networks

The availability and accessibility of existing road systems, public transportation, and other transportation networks (e.g., air, water) shall be considered when planning and siting EPA facilities. Opportunities for transit-oriented development and community connectivity shall also be considered to maximize access to public transport. Submittal requirements documenting these considerations include the following:

EPA facilities that have a high amount of accessibility to various forms of public transportation can earn up to six points under the LEED-NC 2009 Sustainable Sites category. The eligible types of transportation, distances to bus/train stops, and other requirements are detailed in the LEED Reference Guide.

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

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 highly desirable. A general description of proposed pedestrian and bicycle transportation systems should be included.

Setback distance from nearby airports should be determined.

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.

2.1.7 Utilities

The location, availability, and capacity of existing (and future) utilities and services shall be taken into account when selecting and planning the project site. The siting of facilities near existing communities is strongly encouraged in order to reduce natural and financial resources required for construction and maintenance of utilities infrastructure. Locations and designs for service lines shall comply with local and utility service requirements. Utilities include, but are not limited to, potable water, sanitary sewer, storm sewer, electrical power, and communications (telephone, data).

2.1.8 Historic Preservation

The use, preservation, and rehabilitation of historic buildings for EPA facilities is encouraged,. If the project site will involve preservation and rehabilitation of an existing historic building, a qualified preservation design professional should be involved and integrated with the A/E design team.

Section 106 of the National Historic Preservation Act (NHPA) requires Federal agencies to consider the effects of their undertakings on historic properties. Per 36 CFR Part 800, an undertaking is defined as, “a project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a Federal agency, including those carried out by or on behalf of a Federal agency; those carried out with Federal financial assistance; and those requiring a Federal permit, license or approval.” Section 106 is a requirement for the project proponent, not necessarily the land owner.

Activities at EPA facilities must comply with NHPA procedures when they may affect sites that are listed or eligible for listing in the National Register of Historic Places (NRHP). EPA must determine whether there are properties that are potentially eligible for listing on the NRHP and if the proposed undertaking will affect such potentially historic properties. This process includes consultation with the relevant State Historic Preservation Officer (SHPO) (for projects on Indian lands, the Tribal Historic Preservation Officer [THPO]), the Advisory Council on Historic Preservation, and other identified consulting parties (such as local preservation organizations, neighborhood groups, etc.). While the agency is to consult with these parties, it is up to the agency to make the actual determinations of eligibility and effect. If a potentially historic property is affected by the proposed project, it may become necessary to enter into an enforceable agreement, such as a Memoradum of Agreement, Memorandum of Understanding or Programmatic Agreement, which provides information on specific mitigation measures that must be completed before the proposed project proceeds.

Per Section 112(a)(1)(A) of the NHPA, “each Federal agency responsible for the protection of historic resources, including archeological resources, [is required] to ensure that all actions taken by employees or contractors of the agency … meet professional standards under regulations developed by the Secretary [of the Interior].” The Secretary of the Interior’s Professional Qualification Standards for conducting Section 106 assessments can be found at http://www.nps.gov/history/local-law/arch_stnds_9.htm.

Historically and archaeologically sensitive areas must also be thoroughly investigated prior to EPA’s development of the site. Findings shall be documented to provide direction on whether the area(s) in question may be used or must be preserved for future exploration. Publicly available documents shall be reviewed for 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.

Review of SHPO/THPO site files, state archeaological site files, a site visit and survey of the Area of Potential Effect should be included in the project plan. This work must be conducted by a professional meeting the Secretary of the Interior’s Professional Qualification Standards.

Section 106 assessments can be combined with NEPA analysis. However, Section 106 is independent of NEPA and is required for undertakings whether or not NEPA documentation (such as a Categorical Exclusion, Environmental Assessment, Environmental Impact Statement, Environmental Baseline Survey or Environmental Due Diligence Assessment) is required to be completed. Refer to Section 11.6 in Volume 4, *Environmental Management Guidelines* (the Environmental Management Manual) for additional information on NEPA compliance.

2.1.9 “Smart Growth” Considerations

“Smart growth principles shall be considered and encouraged for the sustainable siting of facilities, where practicable. Refer to the International City-County Management Association (ICMA) publication, *Getting to Smart Growth* (2002) for additional guidance.

Local zoning laws and smart growth guidelines shall be considered and incorporated into EPA facility siting and design. A fundamental component of community sustainability and effective local economic development includes coordination with other long range plans for the area. Facility Managers,Project architects and engineers shall engage relevant planning officials at the metropolitan, county, or municipal level to early in the site selection process to discuss the proposed evelopment and understand local planning goals. Laboratory facilities will likely have different zoning requirements than administrative offices, and the type of facility should be taken into account when addressing smart growth concepts. Relevant siting criteria, as defined by the multiagency workgroup identified undersection 10 of EO 13514 are listed below. These recommended siting criteria strive for more efficient, affordable, and environmentally sensitive growth, and they can be integrated with other design criteria discussed in the Manual. In addition, environmental justice issues shall be addressed, as necessary. If an environmental justice review is required, a report shall be provided to EPA early in the design processes, over and above any required community reviews.

EPA Project architects and engineers (A/Es) shall implement the following sustainable siting criteria where practicable:

- **Promote efficient travel and ensure transit access**. Siting decisions should promote a variety of transportation choices for employees and visitors to the facility, with a particular focus on encouraging public transportation and promoting transit oriented development.

- **Locate in existing central business districts and rural town centers.** Prioritize existing central business districts and rural town centers when selecting sites for facilities to strengthen the local economy and integrate the EPA presence into a community.

- **Promote walkability and bikability**. The location should be served by safe and convenient pedestrian and bicycle facilities that support employee access to goods, services, and housing.

- **Locate near or be accessible to affordable housing.** Assure that the site has proximity to a sufficient amount of housing affordable to the employees of the proposed facility and/or proximity to transit that serves areas with housing affordable to the employees of the facility.

- **Foster greyfield/brownfield infill development.** When possible, priority should be given to those locations that would restore previously developed, abandoned or underused locations, including those that have undergone proper remediation.

- **Consider adaptive reuse of historic buildings and districts.** Older buildings that no longer serve their original purpose provide EPA a unique opportunity to locate in existing commercial districts that have local significance and can effectively integrate the federal presence into existing commercial areas

- **Use existing resources.** Siting decisions should maximize the use of existing resources wherever possible by locating in areas that are well-served by water, sewer and other relevant public infrastructure, in existing buildings, and in historic buildings and districts

- **Preserve the natural environment**. Avoid sites that would harm important resources or disrupt efforts to restore or protect local ecosystems or natural resources.

- **Consider impact on EPA scope 3 emission reduction goals.** Facility planners should consider the impact of both worker and visitor commutes to the potential sites on achieving agency Scope 3 reduction goals.

2.2 Promote Climate Change Adaptation Planning**: Global warming is causing climate patterns to change (e.g., major changes in temperature, precipitation,**

wind patterns, and sea level). Therefore, regional and agency climate adaptation planning should be taken into consideration to support well informed decisions when siting new locations. Relevant Codes and Standards

The design guidelines presented in this chapter are designed to comply with the most recent edition of the following technical codes, standards, and guidance documents:

- American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) 31-03, *Seismic Evaluation of Existing Buildings*
- American Society of Testing and Materials (ASTM) E1527-05, *Standard Practice for Environmental Site Assessments: Phase I Environment Site Assessment Process*
- ASTM E1903-97 (2002), *Standard Guide for Environmental Site Assessments: Phase II Environment Site Assessment Process*
- American Land Title Association (ALTA) and American Congress on Surveying and Mapping (ACSM), *Minimum Standard Detail Requirements for Land Title Surveys*
- National Oceanic and Atmospheric Administration (NOAA), Federal Geodetic Control Committee (FGCC), Standards and Specifications for Geodetic Control Networks
- Interagency Security Committee (ISC), *Security Standards For Leased Space* and *Security Design Criteria for New Federal Office Buildings and Major Modernization Projects: Part I and Part II*
- International Building Code (IBC), International Code Council
- National Fire Protection Association (NFPA) Codes and Standards
- U.S. Army Corps of Engineers (USACE) surveying standards: Engineer Technical Letter (ETL) 1110-1-183, Engineer Manual (EM) 1110-1-1000, EM 1110-1-1002, EM 1110-1-1003, EM 1110-1-1005, and EM 1110-2-1003
- Implementing Instructions- *Sustainable Locations for Federal Facilities*
- *Guidance for Federal Agencies on Sustainable Practices for Designed Landscapes*

While design requirements and parameters will vary based upon a project's POR, the guidance in this chapter forms the basis of the POR. In addition, all planning and siting must comply with applicable federal, state, city, and local codes, regulations, and ordinances.

2.3 Pre-Development Investigations

Pre-development investigations (PDIs) are required for all projects. A PDI may include some or all of the following: land surveys, geotechnical and subsurface investigations, environmental investigations, stormwater hydrology investigations, and ground source heat pump (GSHP) feasibility investigations, as applicable. The purpose of the PDI is to provide EPA with sufficient and pertinent data to allow a complete evaluation of the physical conditions of the given project site. The EPA Project A/E shall review the PDI to determine key design parameters, constraints, and considerations for the project.

A key component of the PDI is the site resource inventory and analysis. This 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 analyses and drawings. This plan shall indicate the acres of land that are suitable for construction. The site resource inventory and analysis shall include, but shall not be limited to, the following:

- The site overview, including location, parcel delineation and acreage, existing zoning, and adjoining land uses

- Physical site characteristic analyses, including slope analysis, elevation analysis, existing vegetation identification, hydrology analysis, geological and soils analysis, site analysis, buildable areas analysis, wetlands analysis, solar and shadow studies, and analysis of prevailing winds

- Utilities overview and analysis, including stormwater drainage, potable water, sanitary sewer, electrical power and communications, and mechanical systems.

In addition, the EPA Project A/E shall consider the local 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/standoff distances, 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.

It is recommended that an on-site investigation and review be conducted, which includes representatives of EPA, the A/E design contractor, and the site owner representative, to 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.

Some of the PDI activities may be performed before or after the site resource inventory and analysis is completed. Requirements and guidelines, as they pertain to specific pre-development investigations, including land surveys, geotechnical/subsurface investigations, and hydrologic analysis, including existing on-site and off-site stormwater management facilities that serve the site, are discussed below.

2.3.1 Land Surveys

Land surveys shall be performed for all applicable construction projects, typically for projects involving site work. All land surveys shall be performed by, or under the supervision of, a professional engineer and/or land surveyor registered in the state of performance. Construction, control, property, and topographic surveys shall be conducted in coordination with the appropriate EPA authority and the project A/E design firm. The land survey may be contracted separately or may be included in the scope of the project for the A/E contractor.

At a minimum, the survey(s) shall show legal property boundaries, easements, and legal restrictions, as well as all anthropogenic 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 GSA publication PBS-P100 (2005 or most recent version) and *Minimum Standard Detail Requirements for ALTA/ ACSM Land Title Surveys* (2005), as applicable. The degree of accuracy of construction, control, property, and topographic surveys shall be consistent with each survey.

Engineering stake-outs shall be prepared for all foundation footprints, to verify that the footprint is entirely within the property legal description. Where requested, construction staking and as-built surveys for new EPA facilities shall comply with local standards and with practices approved by the appropriate EPA authority.

Survey field notes shall be legibly recorded, and field notes and final plat-of-surveys shall be furnished to the appropriate EPA authority and EPA Project A/E. Any boundary surveys and recorded maps shall be forwarded and submitted to the appropriate EPA authority and Project A/E.

Specific survey control and monumentation requirements are discussed in the following sections.

2.3.1.1 Survey Control

The appropriate EPA authority shall be responsible for establishing, recording, and perpetuating primary on-site horizontal and vertical control monumentation. The appropriate EPA authority shall also be responsible for correlating primary site-specific horizontal and vertical monumentation with that of other appropriate agencies. In addition to ALTA/ACSM requirements, all surveying and mapping shall conform to the USACE standards listed in Table 2-2 and/or state survey standards, whichever are more stringent.

Table 2-2: Survey Standards for EPA Facilities

Survey Type	Survey Standard	Publication Name
Global Positioning System (GPS)	ETL 1110-1-183	*Using Differential GPS Positioning for Elevation Determination*
Photogrammetry	EM 1110-1-1000	*Photogrammetric Mapping*
Monumentation	EM 1110-1-1002	*Survey Markers and Monumentations*
GPS control	EM 1110-1-1003	*NAVSTAR Global Positioning System Surveying*
Control and Topographic Surveying	EM 1110-1-1005	*Engineering and Design: Control and Topographic Surveying*
Hydrographic survey	EM 1110-2-1003	*Hydrographic Surveying*

Applicable datums include the North American Datum of 1983 (NAD 1983), and to the National Geodetic Vertical Datum of 1929 (NGVD 1929), North American Vertical Datum of 1983 (NAVD 1983).

2.3.1.2 Monumentation

Requirements with respect to monumentation are as follows. For <u>temporary control</u> monuments, the following requirements apply:

- 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 locations 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 ¾-inch diameter iron pipe with a minimum length of two 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 USACE.

For permanent control monuments, the following requirements apply:

- 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 the 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 NAD 1983, and to 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 USACE standards and specifications.

- Permanent survey monuments shall be identified as prescribed by USACE 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.

For benchmarks, the following requirements apply:

- 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 three-mile radius of each new development area. Elevations shall be referenced to NAVD 1983 or to NGVD 1929. Level section misclosures between fixed benchmark elevations shall equal or exceed third-order accuracy, as defined in NOAA's 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.

For utilities, roadways, and parking areas, the following requirements apply:

- 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 features)
  - 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.

For 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.

2.3.2 Geotechnical/Subsurface Investigation

For projects involving site work, subsurface/geotechnical investigations are required and shall be conducted by qualified A/E contractors. Subsurface and geotechnical investigations may take place during site selection, building design, and/or construction.

Preliminary subsurface exploration shall be performed by a licensed geotechnical professional engineer (P.E.) (geotechnical engineer). (In many cases, the P.E. may be a licensed civil engineer, and geotechnical expertise must be demonstrated through experience [i.e., résumé]). The 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 and submittal requirements should conform to the guidelines outlined in GSA PBS-P100, Appendix A, Section A.5 (2005 or most recent version), as applicable. The geotechnical engineer should include in his/her report how best to address site-specific situations, such as soft soils, non-native fill materials, and unstable surfaces and subsurface features (landslide, subsidence, earthquake hazard, etc.).

Subsequent subsurface geotechnical investigations shall be performed under the direction of a licensed P.E. For permanent structures, subsurface conditions shall be determined by means of exploratory soil borings or other methods that allow the engineer to adequately determine soil and groundwater conditions. A profile of soil permeability, for use during design of the site stormwater management system, shall be determined using ASTM D3385-09, *Standard Test Method for Infiltration Rate of Soils in Field using Double-Ring Infiltrometer* or ASTM D5093-02 (2008), *Standard Test Method for Field Measurement of Infiltration Rate Using Double-Ring Infiltrometer with Sealed-Inner Ring*. Data obtained from previous and preliminary subsurface investigations shall be used, along with any additional investigations at the location that are deemed necessary. 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 dynamic 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. Possible mitigating measures (e.g., piers, piles, caissons, dampers, etc.) shall be evaluated (refer to discussion under Geologic Hazard Investigation below).

Results and engineering recommendations from subsurface investigations shall be submitted to and reviewed by the EPA Project A/E and the A/E design/construction contractor. Additional subsurface investigation requirements and documentation are discussed in the following sections.

2.3.2.1 Groundwater Investigation

A groundwater investigation shall be performed for projects involving site work, and specifically for projects involving the selection of a dewatering control system. The investigation shall be conducted by a qualified A/E contractor, which shall examine the character of subsurface soils, groundwater conditions, and groundwater quality. 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 electro-analogous methods discussed in federal Unified Facilities Criteria (UFC) 3-220-05.

2.3.2.2 Geologic Hazard Investigation

During the planning and siting phase, a geologic hazard report shall be prepared for all new building construction in regions of low, moderate, and high seismicity, except for structures located in regions of low seismicity designed to the Life Safety Performance Level (LSPL), as defined by ASCE/SEI 31-03. In-depth geologic hazard investigations are not generally required for minor facilities for which earthquake damage would not pose significant risk to building occupants or the property. However, in general, new building complexes and high-rise buildings shall have a thorough geologic hazard investigation performed. If the geologic hazard investigation is not a stand-alone report, it shall be addressed in a section of the geotechnical and subsurface investigation report, and it shall include recommendations for hazard mitigation. Geologic hazards to be considered and avoided when siting the facility include, but are not limited to, active fault lines, areas with soils susceptible to liquefaction, and zones susceptible to slope failure or landsliding. Refer to GSA PBS-P100 Appendix A, Section A.5 (2005 or most recent version) for additional guidance on geologic hazard report requirements and applicability.

2.3.3 Environmental Investigations

Environmental investigations shall be peformed prior to activities on a project site. As part of the environmental investigations, available historical records should be thoroughly reviewed to determine if contamination is present. EPA project managers and/or facility managers will evaluate the effects that construction activities will have on the local environment. Under the purview of NEPA, a Categorical Exclusion (CX), Environmental Assessment (EA), or Environmental Impact Statement (EIS) may be required. For additional information in determining applicability and project requirements for NEPA review, refer to Section 2.5 of this Manual.

In addition, projects involving acquisition, transfer, or termination of EPA interests in a real property must comply with the Community Environmental Response Facilitiation Act (CERFA), the Federal Property and Administrative Services Act (FPASA), and 40 Code of Federal Regulations (CFR) 373. Compliance with these requirements is facilitated through an Environmental Due Diligence Process (EDDP), which will identify, document, manage, and mitigate potential contamination associated with EPA's interest in the property. Performing EDDP Phase I/II/III Environmental Site Assessements (ESAs) and reviews of the project site are a component of complying with these requirements. For additional information in determining applicability of, and project requirements for, EDDP review, refer to Section 2.6 of this Manual.

Results from the NEPA and EDDP environmental investigations will be reviewed by the appropriate EPA authority and the EPA Project A/E. Refer to Chapter 12 of Environmental Management Manual for additional information.

2.3.4 Stormwater Hydrology Investigation

Stormwater hydrologic analysis shall be performed in accordance with applicable local and state regulations. The stricter of EPA stormwater management requirements or the local or state code shall prevail. Local regulations vary, with hydrologic analyses and investigations often required for sites based on size of the site and the estimated pre-/post-development discharges. The EPA Project A/E shall consider the impacts that the project will have on the site and local environment with respect to surface water quality, drainage, and runoff (during both construction and longer-term operation of the project). In addition, the stormwater hydrology investigation will assist in any stormwater design of the project site. For construction of new EPA facilities (or renovations/changes at existing facilities) that increase the impervious area of the site by 5,000 square feet or greater, the predevelopment hydrology of the property shall be maintained or restored to the maximum extent feasible, with respect to temperature, rate, duration, and volume (EISA, Section 438).

Where available, local precipitation data shall be used in lieu of regional data for site-specific hydrologic modeling. The following 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.

For the rainfall intensity, 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. At a minimum, the rainfall intensity shall be the 95th percentile rainfall intensity based on at least the last 30 years of data, wherever available. The 95^{th} percentile rainfall intensity is the rainfall intensity that 95 percent of storms do not exceed. In accordance with EPA's EISA

Section 438 Technical Guidance for Stormwater, the facility must have stormwater controls that retain 100 percent of the runoff from the 95th percentile event and all smaller events. "Stormwater controls" in this context refers to low impact development (LID) measures (also called wet weather green infrastructure (WWGI)); these are described in detail in Section 3.2 of this Volume. The technical guidance can be downloaded at:

(http://www.epa.gov/owow/NPS/lid/section438/pdf/final_sec438_eisa.pdf)

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 NOAA/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.

The hydrologic analysis shall also be a component of the site resource inventory and analysis (refer to the discussion on pre-development investigations in Section 2.2 of this Manual). In addition, it will assist with the site development design, particularly for stormwater management design.

2.3.5 Ground Source Heat Pump Investigation

EPA encourages the use of ground source heat pump (GSHP) systems (often referred to also as geoexchange or geothermal systems), where practicable. Refer to the following sources for additional information on GSHP systems:

- New York State Energy Research and Development Authority, *Geothermal Heat Pumps* (http://www.nyserda.org/programs/geothermal/default.asp)
- New York City Department of Design and Construction (DDC), *Geothermal Heat Pump Manual* (August 2002)
- Public Renewables Partnership, Geothermal Resources (http://www.repartners.org/), including *Survey of Geothermal Heat Pump Regulations in the U.S.* (2006)
- U.S. DOE, Energy Efficiency and Renewable Energy, Geothermal Technologies Program, *Geothermal Heat Pumps* (www.eere.energy.gov/geothermal)
- Geothermal Heat Pump Consortium (www.geoexchange.org).

A pre-development investigation for GSHP systems is necessary to determine the feasibility, costs, and benefits of such a system at the project site. A life cycle cost analysis of alternatives must be developed and considered in the selection of equipment or systems (EPAct, Section 101). In addition, a test well should be installed to evaluate information such as water temperature, water chemistry (e.g., salinity, iron content), bedrock character, and bedrock thermal conductivity. Engineering recommendations resulting from the GSHP pre-development investigation shall be submitted to and reviewed by the EPA Project A/E and the A/E design contractor for the potential GSHP system's feasibility, potential energy savings, estimated costs, and other impacts. If a project site is a viable candidate for a GSHP system, a certified geoexchange designer shall be responsible for designing and incorporating a system with the rest of the project design.

Refer to Section 6.7.7 for design criteria for GSHP systems, as well as designer and installer certification requirements. Additional land and regulatory requirements that shall be taken into account during the GSHP investigation are discussed below.

2.3.5.1 Land Requirements

A GSHP system may be applicable for both existing and new buildings, and it is highly dependent upon the project location. The availability (or lack) of land can define the design options for a GSHP system. Consideration should be given for the possibility of horizontal or vertical installation of geoexchange piping. If regional soil conditions include extensive hard rock, a horizontal installation may be the most viable option.

In addition, depending on state or local requirements, the GSHP system's type and location may be restricted to be sited away from water supply wells, existing/known contamination sites, septic tanks, storage tanks, or other subsurface obstacles and conditions. The pre-development investigation shall determine land and location requirements with respect to local, state, and federal regulations, because local and state zoning requirements vary.

2.3.5.2 Federal, State, and Local Requirements or Prohibitions

While GSHP systems themselves are not widely regulated, re-injection and discharge from GSHPs are subject to EPA regulation, as follows:

- The Underground Injection Control (UIC) Program regulates injection of fluids into the subsurface, and EPA reporting requirements exist for injection of water to a return well for GSHP systems.

- The discharge of water from an open loop system to a surface body of water may require a National Pollutant Discharge Elimination System (NPDES) permit.

In addition, some state and local governments require notification and registration prior to installing GSHPs. The pre-development investigation shall determine applicable requirements with respect to local, state, and federal regulations and ordinances.

2.4 Minimizing Impacts of Facility Construction Projects

2.4.1 Topography/Cut and Fill

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. It also can contribute significantly to airpollutants and greenhouse gas emissions. EPA encourages a sustainable design approach, to first minimize the total amount of grading and then come as close as possible to balancing cut and fill on the site. Refer to Section 3.8 of this Manual for additional guidance on earthwork cut and fill.

2.4.2 Site Aesthetics

Existing natural features on the site should be preserved and used as a starting point for the overall site design. Where possible, the facility should make a positive visual contribution to the landscape. The landscaping of the site shall create an environmentally sensitive and aesthetically attractive design. The natural environment should blend with the proposed new construction to the greatest extent possible.

2.4.3 Floodplains and Wetlands

Facility siting shall minimize destruction, loss, or degradation of wetlands. To the extent possible, EPA shall meet the requirements of EOs 11988 and 11990, which govern federal actions related to floodplains and wetlands, respectively. When siting the facility, EPA shall:

- Locate the 100-year floodplains in the area. If floodplains are located near the site, the boundaries should be delineated on all surveys and site plans. New facilities should not be located within the 100-year floodplain. To the extent possible, facilities shall not be sited in areas subject to flash floods.

As described earlier, EPA facilities should not be sited in floodplains or wetlands. Fulfilling this requirements also may aid in obtaining a LEED-NC 2009 point under the Site Selection Credit.

- Avoid 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 on wetlands not located in a floodplain.

- Identify, consider, and, as appropriate, implement alternative actions to avoid or mitigate adverse impacts to 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 environmental review requirements under 10 CFR 1022 and NEPA.

All EPA construction activities that have a potential for significant impact on wetlands shall comply with the requirements in Section 404 of the CWA. Only after avoidance and minimization criteria are satisfied can wetlands mitigation be considered. In establishing mitigation requirements, the design team should achieve a goal of no overall net loss of wetland values and functions, meaning a minimum of one-for-one functional replacement with an adequate margin of safety to reflect scientific uncertainty. An EA or EIS under NEPA review requirements must be prepared for each individual wetlands construction permit application. The USACE is the agency that grants the permits. Refer to Section 2.5 of this Manual and Chapter 11 of the Environmental Management Manual for more information about NEPA review.

2.4.4 Stormwater Runoff

Local code requirements for stormwater detention and retention must be followed. For new construction of EPA facilities that increase the impervious area of the site by 5,000 square feet (or greater) or renovations/changes at existing facilities that increase the impervious area by 5,000 square feet (or greater), the predevelopment hydrology of the property shall be maintained or restored to the maximum extent feasible, with respect to temperature, rate, volume, and duration (EISA, Section 438). Site plans shall incorporate QC measures that reduce the concentration of pollutants in stormwater prior to discharge into receiving waters. Construction sites that disturb areas of one acre or greater will be required to obtain a NPDES permit, including developing a site stormwater pollution prevention plan (SWP3). Parking lot retrofits and rebuilds also must meet the EISA requirements.

stormwaterFor guidance on stormwater management and LID strategies, refer to Section 3.2 of this Manual, as well as Chapter 4 of the Environmental Management Manual.

2.4.4.1 NPDES Discharges

Construction activities at EPA facilities that disturb one or more acres of land will be required to obtain a NPDES construction general permit (CGP). The specific CGP permit and application requirements are defined by the NPDES permitting authority (state or federal); these may vary slightly but generally include:

- Submittal of a Notice of Intent (NOI) that includes general information and a certification that the activity will not impact endangered or threatened species. This certification is unique to EPA's NOI and is not a requirement of most NPDES-delegated state NOIs.

- Development and implementation of an SWP3, describing appropriate BMPs to minimize the discharge of pollutants in stormwater runoff from the site.

- Submittal of a Notice of Termination when final stabilization of the site has been achieved, as defined in the permit or when another operator has assumed control of the site.

The primary method to control stormwater discharges at a construction site is through the use of BMPs. Refer to EPA 833-R-060-04, *Developing your Stormwater Management Plan, A Guide for Construction Sites* (May 2007) for guidance on development of SWP3s and examples of proven stormwater management BMPs. Refer to Chapter 4 of the Environmental Manual for additional guidance on NPDES requirements with respect to stormwater discharges and construction operations.

2.4.4.2 Erosion and Sedimentation Control

Erosion and sedimentation control (ESC) measures (often also referred to as construction storm-water BMPs) and post-construction stormwater management BMPs shall be implemented in accordance with federal, state, and local standards and permits. The site should be properly graded and planted to minimize erosion.

Depending on the permitting authority and project size, an ESC plan may be a requirement as part of the local construction permit and NPDES permit application, integrated with (or over and above) the stormwater management plan or SWP3. If required by the local state permitting authority, the ESC plan should be developed and integrated with the stormwater management plan and SWP3.

2.4.5 Discharges to Publicly-Owned Treatment Works

All wastewater discharges from EPA facilities, including discharges during construction activities, shall comply with Clean Water Act (CWA) requirements, as well as state and local restrictions. Depending on the activities at the EPA site, a wastewater discharge pre-authorization or permit may be required to discharge to the local publicly-owned treatment works (POTW) water treatment facility. For facilities that include laboratory operations or industrial activities, a preauthorization/wastewater discharge permit to the POTW will likely be required. Guidance for compliance with requirements is also provided in the following documents:

- EPA 833-B-83-100, *Guidance Manual for POTW Pretreatment Program Development*

- EPA 831-B-94-001, *Industrial User Inspection and Sampling Manual for POTWs*.

For facilities that will have wastewater contaminants exceeding the requirements set forth by EPA, state agencies, and/or the local POTW, appropriate pretreatment equipment and systems shall be installed prior to discharge to the sanitary sewer, to minimize impacts to the POTW wastewater collection system.

Pretreatment systems (such as acid neutralization systems) shall be installed where required, and shall meet EPA specifications and/or requirements of the POTW and NPDES as applicable. Below is additional guidance for acid neutralization pretreatment systems:

- All non-sanitary 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 POTW.

- The system shall be designed and constructed in accordance with NPDES and the local POTW requirements (40 CFR 403.5, National Pretreatment Standards: Prohibited Discharges).

- 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.

Some POTWs require documentation of a wastewater pretreatment plan for specific types of facilities, depending on their activities and discharges. To ensure compliance with all requirements governing the discharge of wastewater, requirements unique to the local POTW shall be investigated.

Refer to Chapter 4 of the Environmental Management Manual for additional information on wastewater management at EPA facilities.

2.4.6 Process Wastewater Discharges

Depending on the state or local government requirements, process wastewater discharges will have varying permit requirements for discharge to sanitary systems. In addition, process wastewater discharges typically require coverage under state discharge permits in order to be discharged and/or pretreated to bodies of water of that state.

Discharge of treated process water onto facility landscaping with vegetative cover is encouraged, provided that appropriate wastewater pretreatment is feasible and that chemicals used are not harmful to the vegetation. Pre-treatment may include pH correction, metals precipitation, and suspended solids removal.

2.4.7 Air Emissions

The impact of the proposed project on air quality shall be addressed. The assessment shall include all sources of air emissions and comply with the requirements of federal, state, and local agencies. The assessment should determine the required air emissions permits for the facility during construction and after project completion (i.e., construction permits and operating permits). Most air permits are issued by state and local permitting authorities, while some EPA regional offices administer the permits at the federal level.

Effective source control requires that potential sources be clearly identified and addressed. Sources of air pollutants that must be considered include both 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 garages (based on 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 potentially affect air quality at the site must be considered. The locations and forms of adjacent buildings that might result in local wind patterns causing re-entrainment of the facility's own exhausts must be considered and addressed. The design professional must consider the following factors:

- Prior history of the site
- Off-site and on-site sources of air pollution
- Soil particulates and gases (including radon, organic chemicals, metals, and microbes)
- Ambient air quality (and whether or not applicable State Implementation Plan [SIP] reqirements are currently met and pollutants in non-attainment)
- Landscaping (including highly sporulating types of plantings).

If an air quality construction or operating permit is required, it must be obtained prior to construction. In addition, depending on local requirements, if the completed facility is likely to result in increased usage capacities (and thus air emissions), an air quality review may be required to comply with relevant local air quality guidelines and regulations.

For areas where pollution levels for the six national criteria pollutants (i.e., carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, and sulfur dioxide) meet the National Ambient Air Quality Standards (NAAQS), those areas are said to be in attainment of those standards and referred to as Prevention of Significant Deterioration (PSD) areas. When an area is not in attainment of one or more of these standards, the area is designated as "non-attainment" for the pollutant(s) exceeding the standard. Depending on the area for which a facility is sited, the air permit requirements will vary.

Refer to Chapter 3 of the Environmental Management Manual for additional guidance on air permitting requirements. Examples of air permits and requirements are listed below:

- **Point Sources**. Examples of point sources include combustors, incinerators, generators, or boilers that may be constructed as part of the EPA facility. Title V permits, PSD permits, non-attainment/new source review (NSR) permits, or other constrction and operating permits may be required for point sources occurring during construction or subsequent project operations.
- **Mobile Sources**. Mobile source air emissions are likely to result from heavy and light-duty equipment during construction or other vehicles that are used in field investigations. In addition, mobile source pollution may increase around EPA facilities due to an increase in vehicular traffic arriving to and leaving the facility. Depending on local requirements, if the facility is likely to result in increased vehicle usage capacities (and thus air emissions), an air quality review may be required to comply with relevant local air quality guidelines and regulations.

2.5 NEPA Screening and Assessment

2.5.1 Determining Required Level of Screening/Assessment

NEPA regulations apply to all EPA facility construction projects, regardless of size. The appropriate EPA authority and/or the EPA Project A/Es shall be responsible for the NEPA review of projects, and they shall follow the procedures outlined below:

- Determine the appropriate level of NEPA review for a proposed construction project
- Define the significant issues to be analyzed through information gathering, scoping meetings, and public participation
- Evaluate project alternatives, including the proposed action and possible mitigation measures, to determine whether their environmental impacts are significant, not significant, or none at all
- Develop documentation to assist the public and decision-makers in evaluating the proposed action and alternatives.

The NEPA review process is not limited to strictly ecological effects such as air and water quality. Effects to be considered also include aesthetic, cultural, historic, health, and socio-economic impacts.

AEAMB is responsible for ensuring that EPA facility construction projects comply with NEPA. If EPA is working with the GSA to construct new space, the GSA is the lead agency and shall prepare the documentation with the cooperation of EPA on design and facility use specifications. Project managers shall coordinate with GSA in such cases, as needed. NEPA review and documentation may also be included as part of a professional services contract.

There are three levels of effort involved with the NEPA analysis of a proposed federal action, which are discussed in the following section.

2.5.2 Categorical Exclusions, Environmental Assessments, and Environmental Impact Statements

NEPA compliance evaluations and reviews shall be conducted early in the planning and decision-making process for construction projects. By doing so, EPA will be able to identify viable alternatives, assess environmental impacts of these alternatives, provide a basis for informed selection of a preferred alternative, and evaluate measures to mitigate adverse environmental effects of the selected alternative.

EPA projects are subject to the following levels of NEPA review and documentation:

- CX
- EA; or
- EIS.

The EPA Project A/E shall review the proposed action for potential impacts in determining the type of environmental document(s) required for the project:

A CX project is an action that is deemed to have no significant impacts. These actions do not individually or cumulatively have a substantial effect on the human environment. Actions include minor rehabilitation of existing facilities, functional replacement of equipment, and construction of new ancillary facilities adjacent to or appurtenant to existing facilities. These are generally routine actions that normally do not require an EA or an EIS.

When a project does not meet the criteria for a CX, an EA should be prepared. The end result of an EA is a determination of a Finding of No Significant Impact (FONSI) or a determination of significant impacts, in the later case requiring an EIS. Note that if preliminary review of an action reveals obvious significant environmental impacts, the review process should proceed directly to an EIS.

Because the need for an EIS indicates that significant environmental, social, cultural, and/or other impacts are anticipated, EPA discourages the selection of project sites that would require an EIS. If an EIS is required, the planning, development, distribution, and public involvement will normally take eight to 18 months to complete, hence substantially delaying project completion.

The appropriate EPA authority should incorporate NEPA review for a proposed action at the earliest possible opportunity and promote continuous communication throughout the project until the NEPA process is complete. For projects likely requiring an EA or an EIS, a scoping meeting should be employed to help prepare a clear and precise description of the proposed action and to identify reasonable alternatives.

Refer to Chapter 10 of the Environmental Manual and EPA Publication No. 4841, *NEPA Procedures for EPA Facilities* for detailed procedural guidance and information on applicability NEPA review processes.

2.6 Environmental Due Diligence Process Activities and Review

During a property transfer process, several EDDP review activities must be performed by various EPA organizations, including the Office of Administration, AEAMB, and applicable program and regional offices, to ensure that real property is transferred legally, on time, and within budget. These activities can typically be performed either independently or concurrently and include:

- Equipment deactivation and decommissioning
- Facility surveillance and monitoring
- Removal and management of chemicals and hazardous substances
- Permit/license transfer or termination
- Management of personal property and surplus equipment
- Building restoration and improvements
- Coordinating and facilitating the EDDP.

Below is a summary of the EDDP review process, objectives, applicability, and compliance requirements.

Objectives. EDDP review activities should be applied when acquiring, transferring, or terminating EPA's interests in any real property. When terminating EPA's interest in real property, the results of the EDDP shall be used to determine whether an environmental condition notification to purchasers or recipients is required under federal, state, and local law. When transferring property to third parties, the results of EDDP review should be used to establish a baseline environmental record of the property as a defense against future claims.

Applicability. In addition to the past and current site operations and the environmental condition of the property, the type of real property transfer can dictate how many phases of the EDDP are performed. At a minimum, Phase I EDDP activities will be conducted for all EPA real property acquisitions, terminations or closures, and leases. Phase I activities may be performed on internal property transfers as well.

Timeframe. The EDDP start date depends upon the complexity of the facility and/or laboratory operations, the real estate agreement, size of the property, number of facilities, and number of operating programs. If feasible, the EDDP should commence at least one year prior to the anticipated property transfer activity. Regardless of the start date, the EDDP is not final until EPA's environmental liabilities and/or risk with the property are eliminated or minimized and the Agency no longer has an environmental financial interest in/responsibility for the property.

Compliance. EDDP review activities, including ESAs, shall be performed in accordance with CERFA, FPASA, 40 CFR 373, and the ASTM ESA standards (including ASTM E1527 and E1903).

It is important that EPA concurrently evaluate financial, legal, NEPA, operational, occupancy, and other consideratons throughout the EDDP review. For detailed guidance in determining applicability and project requirements for EDDP review, refer to Chapter 11 of the Environmental Manual and EPA 100-B-00-002.

Results from the EDDP review and environmental investigations will be reviewed by the appropriate EPA authority and the EPA Project A/E. EDDP review is comprised of three basic levels, which are discussed in the following sections.

2.6.1 Phase I Environmental Site Assessments, Preliminary Survey and Site Investigation

The purpose of EDDP Phase I activities and ESAs is to qualitatively characterize the site and identify any suspected areas of environmental contamination that may require further investigation or remediation. Phase I activities are usually conducted and funded by the Office of Administration, but may also be funded by EPA Headquarters or Program and Regional offices. Phase I activities may be contracted out, provided that the contractor meets the specifications detailed in *Guidelines for Acquiring and Transferring EPA Real Property and Complying with CERFA*.

Phase I activities typically consist of the following:

- Performing preliminary surveys and site questionnaires
- Conducting a site visit and visual inspection of the subject property
- Interviewing EPA site personnel, local authorities, and other individuals
- Performing a search and review of available records and information
- Compiling and evaluating data
- Developing the Phase I ESA Report.

The results of the Phase I ESA Report shall be used as the basis for a decision on whether the facility is likely to be free from contamination, whether Phase II activities are warranted, and/or whether the potential for contamination is such that other actions should be considered.

2.6.2 Phase II Environmental Site Assessments, Investigation Sampling

Depending on the findings and recommendations described in the Phase I report, several activities may be performed under Phase II. The purpose of the Phase II activities is to confirm the presence or absence of suspected contamination identified in the Phase I EDDP activities.

Phase II activities will be performed by a qualified A/E or environmental firm that meets the contractor specifications highlighted in *Guidelines for Acquiring and Transferring EPA Real Property and Complying with CERFA*. EPA shall act in a management and oversight role during Phase II activities.

Phase II ESAs typically include collecting samples of soil, groundwater, or building materials to analyze for quantitative values of contaminants. If contamination exists, Phase III EDDP activities are undertaken to fully characterize the site contaminants and to perform remediation. However, if Phase II sampling determines that contamination does not exist, the EDDP is considered complete.

2.6.3 Phase III Environmental Site Assessments, Characterization, Remediation, and Decontamination

The purpose of Phase III EDDP activities is to characterize the extent of contamination, identify and implement remedial and decontamination strategies, and eliminate future property environmental liabilities and risks. It is important to note that this is the only phase of the EDDP for which ASTM has not issued standards; therefore, federal, state, and local environmental requirements are the guiding principles for Phase III activities.

As in Phase II, EPA will be acting in a management and oversight role for Phase III EDDP, with the actual work performed by a quialified A/E firm. Three primary steps are involved: planning, implementation, and closeout. In addition, upon completion of Phase III investigations and assessments, further activites commence to ensure that remediation and decontamination are successful at minimizing or eliminating the contamination, liabilities, and risks associated with the subject property.

2.6.4 Asbestos, Lead-Based Paint, Mold, and Polychlorinated Biphenyl- and Mercury-Containing Equipment Surveys and Estimation of Potential Environmental Liabilities

Environmental risks and aspects that must be addressed during the EDDP review as well as during construction and renovation are discussed below. Management plans for asbestos, lead-based paint and mold must be in place before demolition or construction activities begin.

2.6.4.1 Asbestos Surveys

For projects at existing buildings, if there are suspected asbestos-containing materials (ACMs) that could potentially pose health hazards, it is recommended that an asbestos survey and abatement plan be performed by certified personnel prior to construction, in accordance with the Asbestos Hazard Emergency Response Act (AHERA).

Some ACMs may be managed in place provided they pose no threats to human health or the environment, and are in good condition. Possible ACMs include asbestos-cement corrugated sheet, vinyl-asbestos floor tile, and asbestos-cement shingle, among others. Refer to Section 7.7 in Volume 4, *Environmental Management Guidelines* and Guideline 22 in *Safety, Health and Environmental Management Program Guidelines* for additional information on management of ACMs.

2.6.4.2 Lead-Based Paint Surveys

While use of lead-based paint is not permitted in construction of new EPA facilities, existing facilities have the possibility of containing lead-based paint, particularly if the facility was constructed prior to 1978. Lead-based paint that is peeling, chipping, chalking, or cracking may represent a health concern (particularly where children are present) or an environmental concern (e.g., damaged exterior paint).

If lead-based paint is suspected to be in existing buildings at a project site, lead inspection or risk assessment shall be conducted by certified personnel (certifications are generally administered through states or through EPA). If lead-based paint hazards are identified during the inspection, abatement or encapsulation may be required to eliminate the lead-based paint hazards. State or local regulations may require notification of any lead-based paint abatement activity. Depending on the state, debris resulting from construction, demolition, or abatement activities and containing lead-based paint may be required to be managed as hazardous waste Refer to Section 7.5 in Volume 4, *Environmental Management Guidelines* and Guideline 25 in *Safety, Health, and Environmental Management Program Guidelines* for additional information on management of lead-based paint.

2.6.4.3 Mold and Mildew Surveys

While there are no federal regulations specifically addressing mold and mildew in buildings, EPA facilities should provide acceptable and comfortable levels of indoor air quality to their occupants. This includes minimizing health hazards due to mold and mildew. For projects at existing facilities, if there is suspect mold or mildew (likely in locations such as insulation, drywall, carpeting, or other areas where moisture collects), a mold survey shall be conducted prior to construction. If mold and mildew hazards are identified, they shall be removed or mitigated by qualified personnel. Removal and abatement procedures will vary depending on the location and extent of the contamination.

It is important to note that any abatement strategies should address the cause of the moisture, to prevent future reoccurrence of mold problems. In addition, state and local guidelines or requirements should be investigated and followed.

2.6.4.4 Polychlorinated Biphenyl (PCB)-Containing Equipment Surveys

While PCB-containing equipment is banned in new construction of EPA facilities, existing facilities have the possibility of having PCB-containing equipment, particularly if the facility was constructed prior to 1978. Possible PCB-containing equipment includes transformers, capacitors, switches, and other types of electrical equipment and light ballasts used in fluorescent light assemblies manufactured before 1978. PCB-containing equipment is regulated under the Toxics Substance Control Act (TSCA) (40 CFR 761).

If PCB-containing equipment is suspected to be present in existing buildings at a project site, a survey of potential PCB-containing equipment shall be conducted by qualified personnel prior to construction/renovation. Equipment determined to be PCB-containing must be decommissioned and disposed of appropriately in conformance with all applicable TSCA requirements.

Equipment found to be leaking PCB-containing fluid (as well as the media contaminated by the leak) must be disposed at an approved TSCA facility. Refer to Section 7.3 in Volume 4, *Environmental Management Guidelines* and Guidelines 9 and 45 in *Safety, Health and Environmental Management Program Guidelines* for additional information on management of PCB equipment and contaminated media (e.g., soil, building debris).

2.6.4.5 Mercury-Containing Equipment Surveys

EPA defines mercury-containing equipment as a device or part of a device that contains elemental mercury integral to its function (40 CFR 273.9). Mercury-containing equipment includes fluorescent and high intensity discharge lamps and some thermostats and switches. If mercury-containing equipment is suspected to be present in existing buildings at a project site, a survey of mercury-containing devices shall be conducted prior to construction. Equipment determined to contain mercury shall be removed by qualified personnel and recycled or disposed of at appropriately permitted facilities. Lamps that contain a mercury level exceeding the toxicity characteristic for mercury (as determined using the toxicity characteristic leaching procedure [TCLP]) RCRA hazardous wastes and must be managed under the hazardous waste regulations or as universal waste. Mercury thermostats and switches are regulated under the Universal Waste Rule. Refer to Chapter 7.4 in Volume 4, *Environmental Management Guidelines* for more information on management of mercury-containing equipment.

2.6.4.6 Estimation of Potential Environmental Liabilities

EDDP activities are designed to identify potential environmental conditions and risks, and provide the information to allow EPA to address, remove, or remediate the potential environmental conditions and risks at a project site prior to real property transfer. Through the EDDP review process, EPA shall characterize and estimate the extent of environmental contamination, risks, and liabilities to allow for appropriate and well-informed decision-making.

2.7 Security Planning

Site security requirements shall be taken into account and provided for in accordance with criteria established by the appropriate EPA authority. Project and site plan designs shall address building and occupant security while maintaining a setting that is accessible, aesthetically welcoming, and effective. Consideration should be given to incorporating physical security features that also provide visual and functional amenities for the building and its occupants. Security features in existing building areas must be carefully integrated with their surroundings. For example, where setback requirements are difficult to achieve, upgrades to existing building security can be addressed through the design of landscape elements at the perimeter and removal of on-street parking.

Site security design shall incorporate the GSA and ISC security standards, as detailed in the following guidance documents:

- Physical Security Criteria for Federal Facilities: An Interagency Security Committee Standard
- GSA PBS-P100 (2005 or most recent version), Chapter 8
- GSA, *Site Security Design Guide*
- ISC, *Facility Security Determination for Federal Facilities*
- ISC *Security Design Criteria for New Federal Office Buildings and Major Modernization Projects: Part II: Tables, Design Tactics, and Additional Risk Guidelines*
- NFPA 730, *Guide for Premises Security*

The required level of security should be determined (i.e., Level I through IV), based on the EPA facility's activities and operations and upon ISC security criteria for Government-leased space. Table 2-3 summarizes the levels of security based on ISC standards:

Table 2-3: ISC-Recommended Security Levels

	Mission Criticality	Symbolism	Facility Population	Facility Size	Threat to Tenant Agencies
1 Point	Low	Low	<100	<10,000 sq. ft	Low

	Mission Criticality	Symbolism	Facility Population	Facility Size	Threat to Tenant Agencies
2 Points	Medium	Medium	101-250	10,001-100,000 sq. ft	Medium
3 Points	High	High	251-750	100,001-250,000 sq. ft	High
4 Points	Very High	Very High	>750	for >250,001 sq. ft.	Very High

ISC Security Level			
Level I: 5-7 Points	Level II:8-12 Points	Level III: 13-17 Points	Level IV: 18-20 Points

The FSL may be raised or lowered one level at the discretion of the deciding authority based on intangible factors.

Table 2.4 shows recommended minimum security measures for Levels I through IV Government facilities as defined by ISC. Specific physical site security requirements and measures for EPA facilities are discussed in the following sections, including setback/standoff distance, perimeter protection zones, physical barriers, vehicle inspections, site lighting, signage, and landscaping. Refer to Physical Security Criteria For Federal Facilities, An Interagency Security Committee Standards, April, 2010 for specific security criteria the building envelope and electronic system, respectively, based on the site-specific security level.

Table 2-4: ISC-Recommended Minimum Security Measures

Area of Site or Facility	Level I	Level II*	Level III**	Level IV***
Perimeter	• Reserved Government parking • Lighting (exterior)	• Window film	• Secured Government parking	• Closed-circuit television (CCTV)
Entry	• Locks	• Same	• Intrusion detection systems	• Guards • Magnetometers • X-ray screening
Interior	• Secured utility areas • Emergency power • Secured mechanical rooms and roof • Restrict building information • Non-disclosure of	• Same	• Relocate or secure air intakes • Secured return air	• Dedicated HVAC for lobbies, mailrooms, and loading docks • Fire alarm with voice communication • Visitor control • Government-approved identification

Table 2-4: ISC-Recommended Minimum Security Measures

Area of Site or Facility	Level I	Level II*	Level III**	Level IV***
	tenants • Shutdown procedures			
Administrative	• Occupancy Emergency Plan • Identity verification of lessor personnel with routine access to Government space	• Same	• Same	• Same

Source: *GSA/ISC Security Standards for Leased Buildings*

* Includes all Level I security measures.

** Includes all Level I and II security measures.

*** Includes all Level I, II, and III security measures.

2.7.1 Setback/Standoff Distance

Depending on local zoning ordinances, setback or standoff distances may be required for the project. The main purpose of the setback/standoff distance is to maintain a minimum distance separation between a building's perimeter and vehicle parking and roadways.

While the terms "setback" and "standoff" are sometimes used interchangeably, the terms have distinct meanings. Standoff typically refers to the distance between a building/structure and a physical barrier designed to protect it; while setback refers to the distance between a building/structure requiring protection and another building, curb, vehicle, or other object (but not necessarily a hardened perimeter). "Secured" standoff indicates the use of a hardened deterrent or barrier to prevent vehicles of a certain size and speed from breaching the standoff perimeter. "Unsecured" standoff refers to deterrents and design approaches, such as on-street parking restrictions, that enhance security but are not designed to stop a vehicle (the resultant solution may not prevent a breach of the perimeter, but will give the impression of increased security and observation and may deter parked vehicular attacks). Effective use of both strategies in concert can improve quality of life, reducing both the incidence and fear of crime.

Setback and standoff distances can be employed to ensure that the building design includes open space for security and safety, as well as for aesthetic and ventilation purposes. In addition, design criteria for minimum setback/standoff distances limit the access by vehicles that may be carrying explosives or other security threats, thus helping to prevent harmful impacts upon a building and its occupants.

In accordance with local zoning requirements, open space and setbacks shall be provided between structures to accommodate site security, landscaping, and other environmental considerations. While security site design will vary for each facility, the minimum preferred distance for a building's standoff is 50 feet.

2.7.2 Perimeter Protection Zone

After the level of protection needed is determined, the design team should ascertain the standoff zone location and dimensions and, where warranted, establish a hardened perimeter. A complete grade-level perimeter intrusion detection system shall be designed to help prevent unauthorized entry. This system shall be in addition to the primary intrusion detection system and monitored at the same control panel provided for the primary intrusion detection system.

Exterior spaces on the property shall be adequately secured to eliminate the potential of unauthorized individuals gaining access to the property. All entrances to the facility and building perimeter 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 number of building entry points should be reduced, particularly under periods of heightened threat The 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.

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.

2.7.3 Physical Barriers

Physical barriers shall be employed to create obstacles for trespassers and vehicles. Fences, trees, or hedges can create effective obstacles as part of the site perimeter security. Bollards, planters, low walls, water features, hardened street furniture, and landscaped earth berms may also be employed as physical barriers while also being incorporated into the landscaping and site design. Landscaping elements can also serve as physical barriers—refer to Section 2.7.3 for landscaping as it pertains to physical security.

Physical barriers should be visually punctuated and as unobtrusive as possible to pedestrians and building users, and consideration should be given to incorporating exterior physical security features with visual and functional amenities.

Refer to Section 4.14 of this Manual for additional design criteria on physical security measures for the architectural and building envelope. Table 2-5 below summarizes exterior physical barrier elements that can be incorporated into site and standoff security.

Table 2-5: Summary of Standoff Perimeter Physical Barrier Elements

Element	Advantages	Disadvantages	Tips
Bollards	• Have proven performance • Are permeable for pedestrians • Are available in high- and low-cost options	• Are overused • Sometimes are oversized • Are often installed at tight, urban locations where achieved setback does not significantly reduce risk • Require deep foundations that may conflict with underground utilities	• Do not over-specify performance requirements • Use vector analysis to determine appropriate performance requirements for different areas of the site • Take aesthetic cues from building and neighborhood context • Do not rely on bollards

Table 2-5: Summary of Standoff Perimeter Physical Barrier Elements

Element	Advantages	Disadvantages	Tips
			exclusively; layer with other elements and create a varied edge
Sculptural or Seating Barriers and K-rated outdoor furniture	• Can double as informal seating • Are flexible • Create visual interest • Not as overt as other security measures • Used in concert with other hardenening features, can enhance perimeter or standoff security	• Require deep foundations that may conflict with underground utilities	• Design the feature to harmonize with the character of the site (e.g., choice of materials, shapes, sizes)
Walls	• Can serve dual purposes as security and amenity • Low walls can double as informal seating • Enable security to become part of the landscape and therefore are unobtrusive	• Require continuous, deep foundations that may conflict with underground utilities • May impact lines of sight to and from the facility	• Choose a design and materials that continue or accent the character of site architecture and other site amenities • Ensure that the design satisfies barrier requirements by collaborating with a structural engineer during team decision-making process • Mix with permeable barrier elements where access is needed (e.g., at entry points)
Hardened Street Furniture	• Can serve dual purposes as security and amenity	• Requires regular maintenance to be effective aesthetically • Is easy to over-scale and over-engineer	• Develop a family of elements (e.g., bollards, benches, lighting) • Do not overuse • Avoid over-designing and over-engineering
Fences	• Can provide high levels of security • Are made of various materials to suit different styles and applications • Can deter individual intruders	• May impact lines of sight to and from the facility • May weaken secure perimeter (e.g., at gates and entry points) • May create a closed-off appearance if too high, particularly in urban contexts	• Choose different heights and types of materials for specific areas of the site, depending on the level of risk and likelihood of attack • Use at sites where individual intruders, rather than vehicles, are a threat • Consider viligent surveillance or patrols where fences are not appropriate

Table 2-5: Summary of Standoff Perimeter Physical Barrier Elements

Element	Advantages	Disadvantages	Tips
Collapsible Surfaces	• Provide invisible barriers beneath usable space • Allow free circulation and uncluttered site • Extend perimeter into public sidewalks without negative impacts	• May require greater perimeter setback depth, depending on site conditions or use of low walls • Requires that service vehicles (e.g., maintenance and landscaping trucks) avoid collapsible areas	• Incorporate low walls or low bollards to decrease required setback depth • Where setback is sufficient, eliminate use of aboveground walls • Coordinate placement with first responders

Source: *GSA Site Security Design Guide*, pp. 46-47.

2.7.4 Perimeter Vehicle Inspection

Vehicle entry points shall be convenient and accessible to general traffic, while secure/limited access areas should be separate to enable perimeter vehicle inspection. In addition, limiting the amount of ingress driveways to the site is recommended.

For larger buildings equipped with a parking facility, the parking facility shall be enclosed and equipped with a perimeter sensor system and gates. The gates shall be equipped with a computerized access control system, and EPA card readers shall be installed at access points. Where practicable, and if the POR design necessitates, a guard gate shall be utilized at the facility's ingress entrance or parking entrance to enable perimeter vehicle inspection.

Refer to Section 4.14 of this Manual for additional design criteria on physical security measures for the architectural and building envelope, with respect to vehicle and building entrances.

2.7.5 Site Lighting

. Site lighting shall be designed to enhance safety and security on the site, provide adequate lighting for nighttime activities, andhighlight any special site aesthetic features. The ISC Physical Security Criteria, April 2010 indicates specific lighting criteria based on the level of protection appropriate for the site. Lighting criteria at sites utilizing minimum security measures include exterior lighting and entrances and exits, and possible parking garages or lots. Lighting criteria at sites utilizing maximum security measures also include walkway, and building perimeter lighting.

Security lighting is an essential element of an integrated physical security program. The purpose behind a security lighting system is to deter criminal activity by reducing stealth approach opportunities. Criminals and vandals are more likely to be active in places where there is little or no lighting. Organizations in both the government and commercial sector have found security lighting can reduce criminal activity and enhance the environmental safety.

Lighting design should account for obstructions. Objects that obstruct the uniform distribution of light limit the effectiveness of security lighting. Obstructions can be in the form of trees, projections or relief on building facades, or parked vehicles. To reduce shadowing, obstructed views should be lit with more than one fixture from more than one direction. In addition, lighting design should optimize the use of reflectance. Reflected light generally enhances the effectiveness of security lighting. Light colored surfaces such building facades, perimeter walls, and concrete walks and drives, increase reflectance. Reflectivity is also affected by surface texture. For example a stucco wall will diffuse light (scatter the reflection) more than a glass curtain wall or painted steel column.

Where visible lighting is not feasible, practical or aesthetically desired; IR illuminators should be considered to supplement CCTV systems to reduce signal to noise ratio and bandwidth requirements which directly affect video quality and storage needs. The IR illuminator should emit consistent and diffuse light output in such a manner as to avoid “hot spots” (small areas of increased lighting within the beam pattern). The wavelength of the IR illuminator must be compatible with the IR corrected lens of the CCTV cameras used. Objective video quality based on benchmarks by the Video Quality Experts Group (VQEG) metrics standardized as ITU-T Rec. J.246 and J.247.

Lighting shall be community-responsive and identify potential light trespass issues before lighting design completion. Generally, floodlighting directed towards the perimeter of a property should not exceed 65° above the vertical plane. Lighting projected upward, such as building lighting, should be designed and aimed to minimize stray light.

All exterior lighting shall incorporate fully-shielded luminaires or use IESNA-compliant low lighting level semi- or full-cutoff fixtures. For additional specifications and requirements, refer to Chapter 9 of ASHRAE 90.1 (latest version) or the Uniform Facilities Criteria (UFC) 3-530-01, 22 August 2006 (or latest version), Table 5-2.

Refer to Illuminating Engineering Society (IES) Security Lightening, Table 8 for additional specific illumination criteria for site lighting systems. for additional specific design criteria for site lighting systems.

All site lighting should have centralized manual control capability. In addition, the lighting should be automated, with a photocell, and should be capable of interfacing with the security systems, for automatic control from the security monitoring room. Avoid the use of time clocks for automating lighting control. They are susceptible to variation from power outage and varying sunrise/sunset during the course of normal seasonal changes.

2.7.6 Security Signage

Posted security signage at restricted areas may include “no trespassing” signs, “restricted area” signs, warnings stating the use of security alarm systems, and/or signs stating the use of video and CCTV surveillance. Security signage should be clear to avoid confusion and shall be posted at appropriate locations (i.e., at 100-foot intervals along restricted areas) Use of clear graphic symbols may be preferred in addition to textual signage to enhance clarity and avoid language or cultural-based uncertainty. Signage shall conform with any applicable Federal and EPA graphic design standards.

Examples of appropriate signage include but are not limited to:

- Prohibiting the unauthorized possession of firearms and dangerous weapons
- Consent to search
- Local building rules and regulations regarding prohibited items
- CCTV surveillance advisory
- Federal property/No Trespassing signs

Refer to 41 CFR 102-74 for further examples.

Exterior signage should be designed to allow for future removal, without significant damage to existing exterior materials. Signage shall also comply with any local signage ordinances.

2.7.7 Landscaping

Site security design shall be integrated with landscaping elements. As discussed previously, physical barriers and other security measures should be incorporated and enhanced through landscaping design. Landscaping elements that can be employed as security measures include trees, hedges, earth berms, and water features. Landscaping that permits concealment of unauthorized personnel or obstructs the view of security personnel and video surveillance should be avoided.

Table 2-6 below provides examples of site security elements that can be incorporated into landscaping . Where possible, all site security elements incorporated into landscaping should be K-rated, such as planters and bollards. In the event that use of all K-rated elements are not feasible due to site considerations, use of a combination of K-rated and non K-rated elements may be an acceptable substitute, Refer to Section 3.3 of this Manual for additional specific design criteria for landscaping.

Table 2-6: Summary of Site/Landscaping Security Elements

Element	Advantages	Disadvantages	Tips
Planters	• Add color and interest, softening hard lines and helping to blend security into the overall site design • Are available in a wide range of styles, to match buildings and landscapes	• Require regular maintenance • Are frequently too large, impeding sidewalk access and creating unattractive visual bulk	• Establish available maintenance resources, including business improvement districts and management staff, before incorporating planters
Water Features	• Provide a barrier that also functions as a focal point or feature of interest • Enhance security without seeming obtrusive	• Require regular maintenance • Require site conditions that can withstand the particular characteristics of water features	• Design water features to blend with landscaping of the site • Integrate seating or landscaping into the hardened walls of water features, so that their security aspects are less apparent
Water	• Can also serve as an amenity (e.g., fountains, decorative pools, and other water features) • May help to achieve sustainability goals (e.g., water reuse/recycling) • Enables security to become part of the landscape and therefore unobtrusive	• Require regular maintenance • May become a drowning hazard	• Coordinate placement of stormwater management areas to enhance security topographically • Consider how natural water features, particularly at suburban sites, can be incorporated into comprehensive site security • Structurally harden features so that they provide unobtrusive protection against vehicles • Consider how fountain will look when not in

Table 2-6: Summary of Site/Landscaping Security Elements

Element	Advantages	Disadvantages	Tips
			operating season
Dry Moats	• Allow for elimination or reduction of walls or bollards • May be less visually intrusive	• Require greater perimeter depth compared to hardened elements • Restrict pedestrian movement across the site	• Use in areas with sufficient setback • Combine with low walls, possibly designed as seats, where there is limited setback
Topography	• Can limit access to the site and serve as a perimeter barrier when shaped thoughtfully • Enables security to become part of the landscape and therefore unobtrusive	• Can create areas of concealment	• Consider sight lines and visibility carefully when designing the topography of a site, to avoid creating possible areas of concealment
Landscaping and Plantings	• Can create natural, repellent barriers, while enhancing the beauty of the landscape • Can screen hardened elements to lessen their visual impact	• Requires regular maintenance • Anything over 6 feet may block sight lines and provide potential hiding places • Can provide attractive hiding places • Root systems may conflict with underground utilities	• Use plants as supplementary protection, in concert with hardened barriers • Use to create a seamless aesthetic transition to surrounding neighborhood • Low-maintenance, native species and drought-resistant species are preferred

Source: *GSA/ISC Site Security Design Guide*, p. 59

3. SITE DEVELOPMENT

The purpose of this chapter is to present guidance and criteria for U.S. EPA Project Architects/Engineers with respect to site development design of EPA facilities. The strategies and procedures stated in this chapter should be used for projects involving new construction or the renovation of existing facilities.

The EPA Project Architect/Engineer (assigned by the EPA Architecture, Engineering and Asset Management Branch [AEAMB]) shall be integral in the site development design of EPA facilities. In addition, one or more Architecture and Engineering (A/E) contractors (i.e., an engineering design and/or construction firm) shall assist the EPA Project Architect/Engineer.

3.1 Relevant Codes and Standards

The design guidelines presented in this chapter are designed to comply with the most recent edition of the following technical codes, standards, and guidance documents:

- Technical codes, standards and specifications
    - American Association of State Highway and Transportation Officials (AASHTO), *A Policy on Geometric Design of Highways and Streets* (GDHS)
    - American Concrete Institute (ACI) 302.1-04 and ACI 302.1R-96
    - ACI 302.2R-06
    - ACI 318-08
    - ACI 336
    - American Petroleum Institute (API) Standard 13A
    - American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)/Illuminating Engineering Society of North America (IESNA) Standard 90.1-2007
    - American Society of Civil Engineers (ASCE) 32-01
    - ASCE 37-02
    - American Society of Mechanical Engineers (ASME) B31.8
    - American Society for Testing and Materials (ASTM) C618
    - ASTM C755
    - ASTM C936
    - ASTM C989
    - ASTM C1319
    - ASTM D422

- ASTM D692
- ASTM D698
- ASTM D1557
- ASTM D1586
- ASTM D1587
- ASTM D2113
- ASTM D2488
- ASTM D6155
- ASTM E1745
- Federal Emergency Management Agency (FEMA) 302, National Earthquake Hazards Reduction Program (NEHRP)
- Federal Highway Administration (FHWA), *Manual on Uniform Traffic Control Devices* (MUTCD)
- FHWA, *Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide*
- National Fire Protection Association (NFPA) 54/ American National Standard Institute (ANSI) Z 223.1
- NFPA 70
- NFPA 88A
- NFPA 241
- NFPA 1141

• Regulations and related standards:

- Energy Policy Act (EPAct) of 2005
- Energy Security and Independence Act (EISA) of 2007
- Architectural Barriers Act (ABA) of 1968 and ABA Accessibility Standard (ABAAS)
- Occupational Safety and Health Administration (OSHA), *Regulations for Construction*
- Executive Order (EO) 13423
- EO 13514

- *Federal Leadership in High Performance and Sustainable Buildings*, signed by EPA on January 26, 2006.[3]

- *Guidance for Federal Agencies on Sustainable Practices for Designed Landscapes*

While design requirements and parameters will vary based upon a project's Program of Requirements (POR), the guidance in this chapter forms the basis of the POR. Site development design and construction work must comply with all applicable federal, state, city, and local codes, regulations, and ordinances. In addition, site development design should follow the guidelines prescribed in the General Services Administration (GSA), Public Buildings Service (PBS) design guide, *Facilities Standards for the Public Builings Service* (PBS-P100). When codes conflict, the most stringent standard shall govern.

3.2 Facility Site Layouts

Facility and site layout is extremely important for the operational effectiveness and energy and environmental performance of sizeable facilities such as those operated by EPA. A complex and interrelated series of decisions must be made as part of the collaborative design process, begun during the pre-design and conceptual design phase and refined throughout the remainder of the design process. Of paramount importance is the ability of the site and facility layout to meet the intended objectives specified in the Agency's Program of Requirements (POR) for the project. Other crucial questions include the following:

- Can the facility and facility design (or add-on if an existing facility) be oriented to minimize solar radiation load for cooling load energy demand?
- Can hardscape parking areas be minimized (e.g., through use of tuck-under parking and through strategies that reduce automobile traffic to the site)? (*This will aid in reducing environmental impacts to storm-water runoff and the heat island effect. Strategies to reduce automobile traffic include access to public transportation, including shuttle buses to/from stations; minimizing parking spaces for automobiles; providing bicycle racks and showers; etc.*).
- Can storm-water runoff be managed so as to avoid high-velocity sheet flows and maximize infiltration and groundwater recharge?
- Can opportunities for xeriscaping and/or eliminating use of turf grasses be explored?
- Can renewable energy technologies be effectively integrated into the design?
- Can the building plan and components be laid out to maximize delivery of daylight into and occupant views out of the interior spaces?
- Can wetlands, forested areas, and other elements of high aesthetic and natural resources value be maintained or created on the site?
- Reuse portions of existing structures that would otherwise be demolished?

[3] This MOU established five Guiding Principles for development more sustainable buildings. The Guiding Principles were incorporated into EO 13423 and EO 13514, and are now mandatory for a specific percentage of EPA's building inventory. EO 13514 states that agencies shall ensure that at least 15 percent of existing buildings and leases greater than 5.000 gross square feet meet the Guiding Principles by FY 2015, with continued progress toward 100 percent.

Refer to Section 4.1.4 for additional information/requirements regarding site traffic layout and flow.

3.3 Stormwater Management

In general, the integrated stormwater management design strategy which EPA encourages is Low Impact Development (LID). This section provides an overview of LID site design and implementation strategies.

- Federal and local code requirements for stormwater permitting, management, detention, and retention must be followed. Specifically, EISA 2007, Section 438 requirements state that for projects with a development footprint greater than 5,000 square feet, the predevelopment hydrology (specifically flow rate, volume, duration, and temperature be maintained where possible.EPA has issued guidance for all Federal facilities describing how this requirement must be met. There are two allowable options:Option 1: Use LID strategies to control the runoff from the 95th percentile, 24-hour rainfall event based on at least 30 years' worth of data OR the runoff from the one-year, 24-hour design storm, whichever is greater. EPA's *Final Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects Under Section 438 of the Energy Independence and Security Act* (December 2009) explains how to calculate the 95th percentile storm event.

- Option 2: Preserve the pre-development hydrology (rate, volume, duration, and temperature).

Runoff from storm events greater than those specified in Option 1 (e.g., 2-, 10-, and 100-year design storms may be managed with structural control measures, such as retention/detention ponds and municipal storm sewers.

LEED-NC 2009 registered facilities can earn one point by implementing measures that either maintain pre-development runoff characteristics and limit stream channel erosion (for undeveloped sites) or substantially reduce runoff volume (for developed sites). Detailed requirements for this credit are contained in the LEED Reference Guide. (Note that new projects must, under Section 438 of EISA, maintain pre-development volume, rate, temperature, and duration of runoff, which may enhance their ability to also achieve this LEED credit).

As stated previously, it is recommended that the above requirements for stormwater management be achieved through a strategy that incorporates LID principles (refer to Section 3.2.1 of this Manual for further guidance on LID). For additional guidance on stormwater management, refer to Chapter 3 of the *EPA Facilities Manual, Volume IV: Environmental Management Guidelines* (i.e., the Environmental Management Manual).

3.3.1 Low Impact Development

3.3.1.1 Overview

LID (also called wet weather green infrastructure (WWGI)) is an approach to land and site development that seeks to maintain or restore the hydrologic impacts of site development using a combination of runoff management strategies, site design techniques, and distributed source controls. The LID approach to site design uses natural and engineered infiltration and storage techniques to control stormwater, resulting in reduced or mitigated impacts on natural resources.

LID incorporates a set of overall site design strategies as well as highly localized, small-scale, decentralized source control techniques known as Integrated Management Practices (IMPs). IMPs may be integrated into buildings, infrastructure, or landscape design. Rather than collecting runoff in piped or channelized networks and controlling the flow downstream in a large stormwater management facility, LID takes a decentralized approach that disperses flows and manages runoff closer to where it originates. Because LID embraces a variety of techniques for controlling runoff, designs can be customized according to local regulatory and resource protection requirements, as well as site constraints. New facilities, redevelopment projects, and capital improvement projects can all be viewed as candidates for implementation of LID. LID concepts and principles include the following:

- Preserve open space and minimize land disturbance.
- Protect and incorporate natural systems as design elements (including wetlands, stream/wildlife corridors, mature forests).
- Decentralize and micromanage stormwater at its source using LID stormwater management practices.

LID practices employ these principles and provide temporary retention areas, increase infiltration, allow for nutrient (pollutant) removal, and control the release of stormwater into adjacent waterways. The A/E design contractor should develop an understanding of the maintenance requirements and life-cycle effectiveness of the LID practices and shall develop an appropriate stormwater management plan for the facility that incorporate LID principles, where possible.

Most LID strategies retain and infiltrate runoff on the project site. This can reduce or eliminate the overall demand for irrigation water, and thus contribute to a facility's ability to earn points under LEED-NC 2009 credits awarded for water efficient landscaping (refer to Section 3.3.3). Particular requirements to quality for these points are contained in the LEED Reference Guide.

Because LID is an integrated design approach, many of the principles discussed in this section may overlap with other sections of this Manual, including stormwater management, landscaping, and hard surface/pavement design. As such, LID design should be fully coordinated with these other aspects of site development planning and design.

For additional detailed guidance on LID design, refer to the following resources:

- EPA 841-F-07-006
- Prince George's County, Maryland, Department of Environmental Resources, EPA 841-B-00-003
- U.S. Department of Defense (DoD), United Facilities Criteria (UFC) 3-210-10.

3.3.1.2 Technologies and Techniques

Because LID site planning strategies create small-scale drainage areas and runoff volumes, the controls are generally small-scale and can be designed to address very specific management issues. Stormwater management controls, if required, should be located as close as possible to the sources of potential impacts. For example, the management of water quality from pavement runoff should utilize devices that are installed at the edge of the pavement.

The objective is to consider the potential of every part of the landscape, building(s), and infrastructure to contribute to the site stormwater management goals. When selecting LID devices and technologies, preference should be given to those that use natural systems, processes, and materials. Once the appropriate site design and LID strategies are considered and proposed, the site design should be re-evaluated to determine whether the stormwater management objectives have been met. Examples of LID site design techniques and strategies include the following:

- Grade to encourage sheet flow and lengthen flow paths
- Maintain natural drainage divides to keep flow paths dispersed
- Disconnect impervious areas such as pavement from the storm drain network, allowing runoff to be conveyed over pervious areas instead
- Preserve the naturally vegetated areas and soil types that slow runoff, filter out pollutants, and facilitate infiltration
- Direct runoff into or across vegetated areas to help filter runoff and encourage recharge
- Provide small-scale distributed features and devices that help meet regulatory and resource objectives
- Treat pollutant loads where they are generated, or prevent their generation.

The following list explains *specific* LID devices or practices that can be employed as part of a LID design strategy:

- **Bioretention**: Vegetated depressions that collect runoff and facilitate its infiltration into the ground.
- **Dry wells**: Gravel- or stone-filled pits that are located to catch water from roof downspouts or paved areas. (Note that if the well's depth exceeds its width, it may be considered a Class V injection well and subject to permitting and regulation under the Resource Conservation and Recovery Act [RCRA]. Dry wells meeting this definition shall not be installed on EPA properties.)
- **Filter strips**: Bands of dense vegetation planted immediately downstream of a runoff source designed to filter runoff before entering a receiving structure or water body.
- **Grassed swales**: Shallow channels lined with grass and used to convey and store runoff.
- **Infiltration trenches**: Trenches filled with porous media such as bioretention material, sand, or aggregate that collect runoff and exfiltrate it into the ground. (Note that if the trench's depth exceeds its width, it also may be considered a Class V injection well and subject to RCRA permitting and regulation.)
- **Inlet pollution removal devices**: Small stormwater treatment systems that are installed below grade at the edge of paved areas and trap or filter pollutants in runoff before it enters the storm drain.
- **Permeable pavement**: Asphalt or concrete rendered porous by the aggregate structure.
- **Permeable pavers**: Manufactured paving stones containing spaces where water can penetrate into the porous media placed underneath.
- **Rain barrels and cisterns**: Containers of various sizes that store the runoff delivered through building downspouts. Rain barrels are generally smaller structures, located above ground. Cisterns are larger, are often buried underground, and may be connected to the building's plumbing or irrigation system.

- **Soil amendments:** Minerals and organic material added to soil to increase its capacity for absorbing moisture and sustaining vegetation. Adding organic matter (e.g., compost) and/or mulch to the upper eight inches of topsoil is one of the most effective stormwater control measures and should be considered mandatory, especially where sub-soil is clay or other poorly drained soil type, unless otherwise directed by the EPA Project Manager. Quality guidelines for compost are a carbon-to-nitrogen ratio below 25:1, pollutant concentration limits below U.S. EPA or applicable local regulations, and no viable weed seeds or invasive plant propagules.

- **Tree box filters**: Curbside containers placed below grade, covered with a grate, filled with filter media and planted with a tree in the center.

- **Vegetated buffers**: Natural or man-made vegetated areas adjacent to a water body, providing erosion control, filtering capability, and habitat. Where practical, buffer widths of 300 feet or greater should be established with intent to provide protection of wildlife migration corridors and habitat for threatened, endangered, and sensitive species.

- **Vegetated or "green" roofs**: Impermeable roof membranes overlaid with a lightweight planting mix with a high infiltration rate and vegetated with plants tolerant of heat, drought, and periodic inundation.

3.3.1.3 Relationship to National Pollutant Discharge Elimination System Best Management Practices

The Clean Water Act prohibits the discharge of any pollutant to waters of the U.S. from a point source unless the discharge is authorized by a National Pollutant Discharge Elimination System (NPDES) permit. Facilities that discharge stormwater from certain activities (including industrial activities, construction activities, and municipal stormwater collection systems) require NPDES permits. These facilities must implement commonly accepted stormwater discharge management controls, often referred to as best management practices (BMPs), to effectively reduce or prevent the discharge of pollutants into receiving waters. Using LID to eliminate the volumes of effluent discharges of permit–requiring activities can help reduce the need for NPDES permits, or demonstrate compliance with NPDES permit requirements. A number of state permitting authorities encourage the use of LID techniques and other innovative stormwater management solutions that reduce pollution associated with runoff. Many states already encourage the use of bioretention, dry wells, filter strips, vegetated buffers, grassed swales, and infiltration trenches. In some cases, stormwater credits may be given for using LID approaches.

3.3.1.4 Benefits and Costs

Long-term costs and benefits should be considered when designing the LID stormwater management system. In addition to benefiting the environment, LID design practices can result in financial savings as well. Some typical cost benefits/savings of a LID site design strategy may include:

- Reduced infrastructural costs for ponds, curbs and gutters, inlets, and pipes

- Reduced life-cycle costs

- Reduced land clearing and grading costs

- Reduced stormwater management costs

An additional opportunity for cost savings is the national trend toward stormwater utility fees for stormwater that exits a property. Fees are typically calculated based upon the impervious area of a lot, such as roofs, roads, and driveways. LID can reduce or eliminate stormwater utility fees by reducing impervious surfaces or promoting infiltration, dispersing flows, and lowering the volume of runoff leaving a site.

Construction costs for LID, however, will vary depending on the characteristics of predevelopment site features, the density of development, the particular LID features selected, and their size and design. For example, the cost of bioretention areas will be a function of the depth of porous backfill and the degree to which underdrains are utilized. The scale of the project, availability of materials, and skills and training of staff are all factors. IMPs involving landscaped areas are often simple to maintain because work can often be performed by landscaping crews or residents; hard structures, such as permeable paving systems with underdrains, may require maintenance that is more specialized.

Increased costs may also result from costs of plant materials, site preparation, soil amendments, underdrains and connections to municipal stormwater systems, and increased project management.

3.3.1.5 Reducing Building Footprints

A LID design approach can contribute to the reduction of the building and/or site footprint. An additional factor to consider when comparing conventional and LID approaches for site design is the amount of land required for the site and/or building in order to implement a stormwater management practice. For example, LID techniques, such as the use of bioretention areas and swales can be incorporated into a landscaping plan. Land that would have been set aside for stormwater retention ponds may no longer be required, thus potentially reducing the site and/or building footprint.

3.3.1.6 Use of Existing Urban Sites

For existing developed and/or urban facilities, EPA encourages the use of a LID approach for upgraded and retrofitted site design. Retrofitting an existing developed area with a conventional stormwater management system may require a considerable amount of space and is likely to involve extensive site disturbance. As discussed previously, LID micro-scale systems generally require less site disturbance for each installment. Thus, LID retrofits may be easier to install than conventional stormwater upgrades or retrofits on sites where urban development has already occurred. In addition, LID systems would reduce stormwater runoff flowing into existing storm drains, and impacts to the local developed infrastructure can be minimized.

3.3.2 Stormwater Harvesting and Reuse

Rainwater or stormwater harvesting refers to the collection, storage, and use of rainwater. Stormwater harvesting is most commonly achieved through the use of rain barrels and cisterns. A typical stormwater capture system consists of collecting runoff from a catchment area (such as a roof) and storing it in a receptacle (such as a cistern) for reuse. Storage receptacles may be in the form of large galvanized steel, fiberglass, polyethylene, or ferro-cement tanks. Stormwater harvesting offers several important environmental benefits, including reduced runoff volumes, as well as reduced pressure on limited water supplies.

Harvesting and reuse of stormwater runoff from the facility site (e.g., for landscape irrigation, toilet flushing, custodial uses) can contribute to reducing post-development discharge rates and quantities. For EPA facilities pursuing LEED-NC 2009 certification, this in turn can aid in obtaining one point under the Stormwater Design—Quantity Control credit. Meeting specific quantitative criteria is required, as described in the LEED Reference Guide.

When captured water is used for landscape irrigation and non-potable uses, sediment filtration is typically the only required treatment process. When captured water is intended for potable uses, additional purification measures are required to ensure its safety. A stormwater harvesting system may incorporate a first-flush diverter (especially if the water is intended for potable use). A first-flush diverter system keeps dust and pollutants that have settled on a catchment area from entering the storage receptacle by redirecting the first flush of water away from the catchment structure. Larger debris and particulates are kept out of the system by placing a screen over each inlet pipe.

It is both logistically and economically advantageous to plan for the integration of stormwater harvesting systems during the design phases of a project. Stormwater harvesting should be considered as an option for all sites, especially sites with:

- Aquifer-based water supplies that are limited or ecologically fragile (i.e., where excessive pumping of groundwater can lower the water table, threatening ecologically valuable surface waters and springs)

- Pumped groundwater that is contaminated or excessively mineralized (hard) and thus requires extensive treatment

- Frequent stormwater runoff and flooding.

Certain recycled stormwater applications may be restricted due to local regulations. Local ordinances may limit applications to landscape irrigation or cooling tower use. In some areas (particularly the western U.S.), capture and storage of rain water on site may violate the water rights of downstream users. Local ordinances must be reviewed for applicability prior to installing a rainwater or stormwater harvesting system.

3.3.2.1 Catchment Area

Most rainwater harvesting system catchment areas consist of an impervious surface such as a building roof. While not all catchment areas meet these criteria, those surfaces most conducive to rainwater harvesting have the following characteristics:

- Does not support biological growth (algae, mold, moss, etc.)

- Is fairly smooth, allowing pollutants and deposited debris to be quickly removed by the first-flush diverter system

- Has minimal or no overhanging tree branches above it.

Gutters and downspouts must be constructed from lead-free materials, such as galvanized steel, or seamless aluminum (EPA does not encourage the use of polyvinyl chloride [PVC] due to the human health and environmental impacts of vinyl chloride). A minimum of two 45-degree elbows shall be installed in order to “snug” the downspout pipe to the side of the building. To avoid overflows, the hydraulic capacity of roof “valleys” must not exceed the hydraulic capacity of the associated gutters and downspouts to remove rain water from that portion of the roof.

In areas where trees overhang or wind-blown leaves or debris may accumulate, leaf removal equipment shall be included and will be one of the following:

- ¼-inch steel mesh in wire frame leaf guards extending along the length of the gutter system

- Funnel filters installed directly into downspouts, or

- Strainer baskets at downspout outfalls.

If funnel filters are used, they shall be placed slightly above the high water level inside the cistern, in order not to become submerged.

First-flush diverters shall be installed on each downspout, to provide removal of smaller debris such as dust, blooms, small leaves, twigs, dead insects, animal feces, and pesticides. Each diverter shall consist of a simple high-density polyethylene (HDPE) standpipe or HDPE standpipe with a floating ball valve just below the outlet tee (non-PVC materials are preferred if cost-effective and feasible). All diverters shall have weep holes and clean-out plugs. The first-flush volume shall be calculated assuming 20 gallons per 1,000 square foot (ft^2) of roof area (or as required by local code).

If stormwater runoff is collected from hardscape areas (e.g., asphalt), depending on local and state code, its uses may be limited to irrigation. In these circumstances, it is advisable to isolate this runoff collection system from any rooftop collection systems (e.g., separate networks, isolation gate valves) in order to preserve the water quality in the latter system.

3.3.2.2 Storage Tank(s)/Cistern(s)

Storage tank(s) or cistern(s) shall be sized based on the following parameters:

- Local precipitation volumes
- Projected intervals between rainfall events
- Facility demand for non-potable water
- Catchment surface area
- Aesthetics
- Life cycle costs.

Tanks may be constructed from fiberglass, polypropylene, hardwood, metal, concrete, or ferro-cement. To prevent leakage, fiberglass tanks shall have integral fittings installed by the manufacturer. Polypropylene tanks installed below ground must have adequate reinforcement (e.g., bands and tie-downs); aboveground polypropylene tanks must be painted or tinted to prevent ultraviolet light (UV)-catalyzed degradation. Tanks made of UV impregnated resin are also a solution that is highly UV resistant. For galvanized steel and hardwood tanks that store water for potable uses (or applications that require similar water quality), a food-grade, permanent polyethylene liner must be included. Galvanized tanks shall be coated using the hot zinc process to minimize corrosion, unless otherwise specified.

Concrete tanks may either be poured-in place or prefabricated (whole or in segments). Fly ash or other pozzolans may be added in proportions suitable to improve resistance to cracking, so long as they do not contain concentrations of heavy metals that may leach into the groundwater at unacceptable levels. A structural engineer must review and approve the reinforcement rod design for in-ground concrete tanks. Ferro-cement mixtures shall not contain heavy metals, and ferro-cement tanks should be painted white to prevent heat gain (unless otherwise specified).

In most applications, aboveground tanks should be installed on a concrete pad. A structural engineer shall review the tank and foundation design. The ground surrounding the pad shall be sloped so as to direct runoff away from the pad. Aboveground tanks shall be opaque and shall be tightly sealed when in normal use to prevent evaporation losses, intrusion by insects and small animals, and/or sunlight (which can stimulate algae blooms).

Aboveground tanks shall be located, where practicable, in a location(s) where gravity flow can provide partial or full pressure for distribution of the collected rain water. In many situations, however, pump(s) and pressure tank(s) will be necessary. To achieve optimal pumping efficiency, distribution pump(s) shall be located as close as possible to the storage tank. A one-way check valve shall be installed between the pump and the storage tank to preclude pressurized backflow. The pump shall be actuated by a low-pressure switch connected to a sensor inside the pressure tank (or at the point of demand). An on-demand pump may be installed in lieu of a pressure tank, with EPA's approval.

A float filter with a 60-micrometer (µm) filter shall be installed inside the cistern or storage tank, in order to draw water from the upper 10 inches to 16 inches of the standing column. The pump shall be specified and installed so as to maintain adequate suction and ensure that water is not bypassing the float filter. To prevent excessive sedimentation, the outfall from each cistern shall be located above the anticipated top of the sediment layer.

As with other facility components and stormwater BMPs, stormwater tanks and cisterns require regular maintenance to ensure a prolonged life. After construction is completed, the tank and related systems should be inspected to ensure they are functioning properly and commissioned along with other site plumbing systems. After building acceptance, regular maintenance should include monthly and semi-annual inspections and cleaning. For example, screens utilized for catching debris, insects, etc. should be cleaned at least annually and after large storm events.

Rain barrels, cisterns, or other systems designed to collect rainwater and that could lead to standing water shall be located away from building HVAC entry points.

3.3.2.3 Conveyance System

Conveyance piping construction and size will vary depending on system design characteristics (e.g., flow rates, head losses), whether piping is buried or above ground, and whether gravity flow or pressurized flow is being utilized. Specifications for both types of piping are included in Section 6.13 of this Manual. Piping for this application will normally be constructed of ductile iron, acrylonitrile butadiene styrene (ABS), HDPE, or other materials as dictated by local code (note that non-PVC materials are preferred if cost-effective and feasible).

3.3.2.4 Pre-treatment Processes

Pre-treatment will depend on the application and on state and local environmental regulations. In most cases, pre-treatment for these applications will consist of some combination of:

- Sedimentation (settling)
- Bag and/or sand filtration
- Activated carbon adsorption.

Other processes that may be employed including UV-chemical oxidation, coagulation and flocculation, pH-induced or chemical precipitation, and/or biological treatment (e.g., trickling filters).

3.3.3 Erosion and Sediment Control

The project site shall incorporate quality control measures that reduce the concentration of pollutants and sediment in stormwater prior to discharge into receiving waters. Construction sites that disturb one acre or more may be required to obtain a NPDES permit and develop a site stormwater pollution prevention plan.

If required by the applicable federal/state/local authority, an erosion and sediment control (ESC) permit and plan may also be a requirement as part of the construction project, in addition to a NPDES permit and stormwater pollution prevention plan. ESC measures and BMPs, in accordance with federal, state, and local standards, shall be used during construction to mitigate potential soil erosion and prevent the migration of sediment into local surface waters.

As a prerequisite for obtaining certification under LEED 2009-NC, EPA facilities must develop an ESC Plan for all construction activities related to the project.

While ESC measures and BMPs generally focus on short-term controls during construction, the A/E contractor should consider the strategies and techniques for stormwater management (described previously), to properly and efficiently integrate those stormwater BMPs with ESC planning, design and implementation.

3.4 Landscaping and Irrigation

3.4.1 General Requirements

The landscaping design process must coincide with the building design process to create a single design that integrates site and building(s). All landscaping and site amenities for the project shall be in accordance with all applicable local, state, and federal codes and industry standards.

If the facility is part of an existing campus or among other buildings in a master-planned development, the landscape design as well as building design must be integrated and compatible with the style(s) of the campus. Landscaping and site amenities shall comply with any master plan design and construction requirements standards. The more stringent requirements shall be used if a conflict exists.

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. The landscape architect shall:

- Preserve existing trees and undergrowth, where appropriate, for buffers
- Review buffer requirements of the local community
- Use existing trees to the extent possible, since the larger size will provide greater immediate impact on-site.

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.

In addition, the following general criteria apply:

- Existing general features (including vegetation and natural terrain) on the site should generally be preserved and used as a starting point for the overall site design.
- 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). Landscaping should be used to 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.

- 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 neighboring building(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.

- For lighting of site and landscaping features, energy efficient exterior lighting with low-voltage or solar powered shall be used (i.e., Energy Star or Federal Energy Management Program [FEMP]-designated products) (EPAct 2005, Section 104). Lighting that reduces light pollution should be considered. Refer to Sections 3.13 and 7.7.3 of this Manual for additional guidance on site and exterior lighting technologies.

- Landscaping should not obstruct views at vehicular intersections, entryways, or crossings.

To meet its obligations under Executive Orders (EOs) 13423 and 13514, EPA requires that all of its laboratories develop and implement Water Management Plans. These plans specify measures to achieve a reduction or elimination of potable water used in landscape irrigation.

Sustainable design practices should be monitored and documented in order to evaluate performance over time and improve the body of knowledge on long-term site sustainability. A site maintenance plan should be developed to ensure that site managers and any maintenance contracts commit to educating maintenance personnel on the goals and implementation of the plan.

3.4.2 Plantings

EPA requires the use of sustainable design principles for landscaping, including plant selection and placement, wherever feasible. EPA also requires that, where feasible, natural landscaping and/or xeriscaping methods be utilized.(refer to Section 3.4.3 below). Plant selection, including turf, shall be based on the plant's adaptability to the region, and the selection of regional, native, and drought-tolerant species is encouraged. Existing vegetation (such as old growth trees) should be evaluated for appropriateness to remain on site; where appropriate, existing trees and shrubs should be protected and additional planting and landscaping may be built around them. Exotic and/or invasive species shall not be used.

As feasible, identify and remove all invasive species on-site and develop and implement an active management plan to prevent new introductions. Develop a comprehensive invasive plant management plan (either as a separate plan or as part of a larger natural resources or operations management plan) that addresses early detection, removal, prevention, and long-term management. This plan should also incorporate Integrated Pest Management Plan (IPM) practices and guidelines including treatments, long-term control (including monitoring), and best management practices for disposal of invasive plant materials to prevent spread. Invasive and/or non-invasive plants may be a character-defining part of a historic landscape or planting. If invasive non-native plants are to be maintained for historic reasons, they should be actively managed so that they do not spread or cause harm to the region.

Plants need to be chosen with their mature size and growth habit in mind to avoid over-planting and conflict with other plants, structures or underground utility lines. EPA also encourages the use of natural landscaping and xeriscaping methods (as discussed in Section 3.4.3).

Where practicable, plants and materials should be purchased from businesses and providers that reduce resource consumption and waste and employ sustainable practices including, but not limited to, use of sustainable soil amendments, reduced irrigation runoff, reduced greenhouse gas emissions, reduced energy consumption, use of Integrated Pest Management (IPM) practices, reduced water consumption, reduced waste, and recycling of all organic matter. Also select those that are grown or produced locally or within the geographic region of the project in order to reduce energy use for transportation and increase demand for local goods. Source materials, plants, and soils within distances specified (soils – 50 miles, aggregate – 50 miles, plants – 250 miles, all other materials – 500 miles) should be considered.

Additional guidelines for selecting plantings are as follows:

- Consider focal or entry area; design main entry area to produce an obvious sense of arrival at facility, and create views as needed.
- Develop color and seasonal interest
- Provide orientation of plantings for the creation of shade and buffers
- Consider site-appropriate formal planting plan or informal, naturalistic plan
- Avoid major plantings in areas where expansion is planned
- Break up large areas of pavement with landscape islands
- Determine irrigitation and 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. Plantings must not block security cameras
- Ensure that lawns slope to provide proper drainage (minimum one percent grade)
- Provide ground cover on severe slopes for aesthetic and maintenance considerations
- Plantings 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
- During construction, existing trees and shrubs should be protected to the drip line or further (unless specific permission from the EPA project manager is given, and compensatory approaches are taken for their protection)

- Protect, and preserve all vegetation designated as special status by local, state, or Federal entities

- Use trees and other vegetation to offset emissions of greenhouse gases from operations; trees and other vegetation can promote long-term storage of carbon.

- Salvaged plants should be reused to conserve resources.

- Do not use wood species listed as threatened or endangered by the Convention on International Trade in Endangered Species (CITES) and the International Union for Conservation of Nature (IUCN).

3.4.3 Natural Landscaping/Xeriscaping

Xeriscaping refers to a site design approach that requires minimal or no supplemental irrigation for landscapes. EPA encourages the use of natural landscaping and xeriscaping design methods – this may also be referred to as drought-tolerant landscaping, zeroscaping, smartscaping, or beneficial landscaping. Low-maintenance landscape design and features shall be used. Sustainable vegetation (e.g., typically native, local/regional, or adaptive plant species) that requires minimal watering and maintenance shall be used to minimize maintenance of the plantings. Use of irrigated turf grass in new landscape design is prohibited.

EPA facilities can earn up to four points toward LEED-NC 2009 certification in the Water Efficiency category if they completely eliminate irrigation, or do not use potable water for irrigation.

The seven widely accepted xeriscaping design principles are listed below, along with applicable practices and guidelines:

- **Planning and design**. Examine the site and all factors that will determine the best design and choice of plants for the area, including drainage requirements, sun exposure and areas of shade, prevailing winds, directional orientation, concrete areas, weather and precipitation patterns, water availability and cost, and existing plant or lawn locations and characteristics.

- **Limited or no turf grass coverage**. Part of xeriscaping involves replacing areas of turf with other plant materials. Turf uses more water than most other plants and thus it should be used sparingly in landscaped areas. For remaining turf areas, drought-resistant species of grass that are native to the area should be selected.

- **Efficient irrigation.** If irrigation is necessary, efficient irrigation strategies should be incorporated with xeriscaping. These include irrigating turf areas separately from other plants, separating high and low water use plants, using subsurface irrigation, and employing drip irrigation technologies. Efficient irrigation strategies and guidelines are further discussed in Section 3.4.4.

- **Soil improvements**. Healthy soil reduces water use and helps plants and turf to thrive. It is recommended to analyze existing soil samples from the site to determine nutrient content and needed treatment, and to then incorporate organic matter and water-retaining material into the soil.

- **Use of mulches.** Organic mulches improve the condition of the soil and allow it to retain more moisture. In addition, mulching helps to control weeds.

- **Select appropriate plants.** Drought-resistant and low water use plants are available to conserve water, replace turf, and create a very appealing landscape. Higher water use plants should only be used in areas with sufficient rainfall or in low-lying areas that receive rain runoff. In addition, plants with like-water demands should be grouped together and watered accordingly.

- **Appropriate maintenance**. Though xeriscaping may reduce maintenance, no landscaping program will thrive without regular maintenance. Maintenance tips include weeding and pruning as needed, properly adjusting and testing equipment, mowing turf to proper heights.

Refer to Section 3.2.2 of this Manual for additional criteria and information on water conservation and recycling technologies. For additional guidance, refer to the following resources:

- U.S. Department of Energy (DOE), FEMP, *Water Efficient Landscaping*
- U.S. EPA, *Water Resources Center, Water Efficient Landscaping: Preventing Pollution and Using Resources Wisely*
- UFC 3-440-02N.

3.4.4 Irrigation Guidelines

Irrigation is discouraged at EPA facilities, except for initial irrigation during the period in which new plantings are settling in and being stabilized. Irrigation should be used sparingly only if necessary. As stated previously, new designs that feature turf grass requiring regular irrigation are generally prohibited at EPA facilities.

Where irrigation is required, outdoor potable water consumption shall be reduced by at least 50 percent (relative to the “conventional” baseline consumption of planting species and densities at the site), through a combination of water-efficient landscaping and irrigation strategies (this guiding principle was introduced in the 2006 Memorandum of Understanding [MOU] and made mandatory by EO 13423). Irrigation systems shall be designed and operated in accordance with local ordinances and guidelines. In addition, EPA encourages the use of high-efficiency irrigation, climate-based controllers, captured rainwater, recycled graywater or condensate water, and/or treated wastewater. Irrigation systems shall provide water to plants only when needed. If possible, the use of <u>potable</u> water for irrigation should be minimized or eliminated; instead, non-potable treated water or rainwater of acceptable quality should be used..

> **EPA facilities that reduce outdoor potable water use for irrigation by 50 percent or greater can obtain two points toward LEED-NC 2009 certification under the Water Efficiency category. In addition, as indicated in the previous section, facilities that completely eliminate use of potable water for irrigation (or have no irrigation at all) can obtain four points.**

Where irrigation is required, high-efficiency irrigation and climate-sensor technologies include drip irrigation systems, micro-irrigation systems, micro-misters, moisture sensors, rain shut-offs, and weather-based evapotranspiration controllers. For example, drip systems apply water slowly and directly to the roots of plants, and moisture sensors save water by ensuring plants receive water only when necessary. Other technologies that can be employed are rainwater collection systems (e.g., cisterns, rain gardens, underground tanks). Wastewater recovery and treatment can also be accomplished on-site or obtained at the municipal level. Recycled wastewater intended for irrigation should be properly treated to tertiary standards.

If, due to dry climate or other site-specific circumstances, permanent irrigation systems are required, this water should be metered separately from domestic water to: (1) ensure that the facility does not pay sewage treatement fees on water being used for irrigation; and (2) effectively monitor, isolate, and repair leaks in the conveyance system.

Increasing the organic content in soils generally increases soils' holding capacity for water. Where feasible, the use of compost or other organic matter and/or mulch shall be added to the topsoil, as specified previously in Section 3.2.1.

Lastly, where applicable, if using contractors for irrigation design, implementation, or auditing, the contractor should be certified through a WaterSense labeled program. To ensure the designed landscape's water requirement meets a basic measure of water efficiency, use the U.S. EPA's WaterSense Water Budget Tool.

3.4.5 Gray Water Recycling for Irrigation

Gray water is usually defined as water from showers, bathtubs, bathroom sinks, washing machines, and drinking fountains. It may also include condensation pan water from refrigeration equipment and air-conditioners, pond and fountain drain water, and cistern drain water. Gray water typically contains a minimal amount of contamination and can be reused for certain landscaping and other non-potable applications. Although public health officials are still debating gray water safety, no reported cases of illness has ever been directly attributed to gray water reuse. In general, gray water recycling is encouraged at EPA facilities for use in landscaping and irrigation applications (i.e., where irrigation is required).

Black water is defined as heavily soiled water from toilets and urinals. Wastewater from kitchen sinks and dishwashers is occasionally included with gray water, but more commonly it is lumped with black water because it contains oil, grease, and food scraps, which can burden the treatment and disposal processes. Both gray water and black water contain pathogens and humans should avoid contact with both, but black water is considered a much higher risk medium for the transmission of waterborne diseases. Though not considered black water, the following water sources should not be included in gray water that is to be used for irrigation:

- Garden and greenhouse sinks
- Water softener back-flush
- Discharge from floor drains(especially discharges from chemical handling areas and decontamination showers)
- Swimming pool water.

Gray water capture and reuse systems shall be designed and constructed in accordance with the March 1997 *Revised California Gray Water Standards* or local codes, whichever is more stringent. Collected gray water shall be routed to a holding tank or reservoir, which shall be equipped with an overflow outlet to the sanitary sewer line and a manual shunt valve. The primary discharge pathway shall be to a subsurface drip irrigation system (sprayers are not permitted). Systems that automatically purge after a set time period (e.g., 12 hours or less) are preferred to prevent odor accumulation. The reservoir must be appropriately vented to release sewer gases, and odor filtering devices (e.g., compost bed, activated carbon, ozone injector, etc.) shall be provided where warranted.

Construction of piping and tanks/reservoirs for gray water will generally be similar to rain water collection systems, except that concrete shall not be used unless coated with an interior smooth liner approved by EPA. Piping for gray water conveyance must be clearly marked "Gray Water Only" (gray water piping should also be a different material [e.g., plastic] than standard copper potable water piping.). The system discharge shall also be marked with a warning that the water does not meet potable water quality standards.

Drip irrigation supply lines shall be (minimum) polyethylene tubing or other non-PVC Class 200 pipe and Schedule 40 fittings. All joints shall be properly solvent-cemented (where necessary), inspected, and pressure tested at 40 pounds per square inch (psi), and shown to be drip-tight for five minutes before burial. All supply lines shall be buried at least eight inches deep. Drip feeder lines may be polyethylene or flexible non-PVC tubing and shall be covered to a minimum depth of nine inches.

Where pressure at the discharge size of the pump exceeds 20 psi, a pressure-reducing valve able to maintain downstream pressure no greater than 20 psi shall be installed downstream from the pump and before any emitter devices. Each irrigation zone shall include a flush valve/anti-siphon valve to prevent back-siphonage of water and/or soil.

The maximum emitter discharge (in gallons per day [gpd]) and minimum number of emitters per gpd of gray water production may be estimated using Table G-3 of the *Revised California Gray Water Standards.* Irrigation fields shall be constructed as follows:

- Number of drain lines per irrigation zone: ≥ 1
- Length of each perforated line: ≤ 100 feet
- Bottom width of trench: 6 inches – 18 inches
- Total depth of trench: 17 inches – 18 inches
- Spacing of lines, center to center: ≥ 4 feet
- Depth of earth cover above lines: ≥ 9 inches
- Depth of filter material cover of lines: ≥ 3 inches
- Grade of perforated lines: Level (minimum); 3 inches/100 feet (maximum).

A mini-leach field system is allowed under the California regulations as an alternative to subsurface drip irrigation. The mini-leach field configuration shall consist of buried perforated piping that is a minimum 3-inch diameter and constructed from HDPE, ABS, PVC pipe, or other approved materials (non-PVC materials are preferred if cost-effective and feasible). A sufficient density of perforations must be provided to adequately convey and distribute the required flow of gray water. Perforated sections shall be packed in clean stone, gravel, or similar acceptable filter material varying in size between ¾ inch and 2 inches. Filter material must be covered with landscape filter fabric (e.g., geotextile) or similar porous material to prevent closure of the voids by earth or soil.

Pre-treatment requirements for gray water will depend on the end use. The most common treatment processes required will be pH adjustment/neutralization, sedimentation to remove gross solids, and filtration to remove fine solids. Disinfection (e.g., chlorination, UV sterilization, ozonation) may also be required (*note that testing for trihalomethanes may need to be instituted if chlorine is added*). For large-scale systems processing moderate to high biological oxygen demand (BOD) loadings, a biological treatment process such as a trickling filter or rotating biological contactor may be appropriate.

3.4.6 Constructed Wetlands to Treat and Recycle Process Water

Constructed wetlands for water treatment are complex, integrated systems of water, plants, animals, microorganisms, and the environment. Constructed wetlands are sometimes a cost-effective and technically feasible approach to treating wastewater and runoff for several reasons:

- Wetlands can be less expensive to build than other treatment options.
- Operation and maintenance (O&M) expenses (energy and supplies) are often lower than other methods.
- O&M require only periodic, rather than continuous, on-site labor.
- Wetlands are able to tolerate fluctuations in flow due to hydraulic and geochemical buffering capability.
- Wetlands facilitate water reuse and recycling or improve the quality of the wastewater to enable managing it via other means.

In addition, constructed wetlands:

- Can be built to fit harmoniously into the landscape
- Provide numerous benefits in addition to water quality improvement, such as wildlife habitats and the aesthetic enhancement of open spaces
- Are an environmentally-sensitive approach that may be viewed favorably by project stakeholders.

A constructed wetland consists of a properly-designed basin that contains water, a substrate, and, most commonly, vascular plants. These components can be manipulated in constructing a wetland. Other important components of wetlands, such as the communities of microbes and aquatic invertebrates, usually develop naturally once the correct conditions are provided.

The primary impediment to use of this treatment approach is lack of available land. One means of addressing this problem is to use a subsurface flow, rather than an open or surface flow, configuration. In addition, because constructed wetlands can simultaneously serve as detention areas for stormwater runoff, it may be possible in some cases to replace a simple detention area with a wetland that provides both hydraulic retention and a living area for contaminant filtration and removal.

While constructed wetlands are complex systems that should be designed only by an environmental engineer or wetlands scientist with the necessary empirical experience (in many cases, a multi-disciplinary design team may be the best approach), the design shall follow a generally accepted methodology such as that proposed in *Treatment Wetlands*, written by R.H. Kadlec and R.L. Knight.

3.4.7 Using Shading to Mitigate Heat Island Effect

Vegetation can provide shade to buildings and paved areas as well as cool the surrounding air through evapotranspiration.

Trees, large shrubs, non-invasive vines, and other vegetation should be used to shade large hardscape areas and prevent solar heat gainto building interiors. Trees should be placed to provide shady sitting areas, reduce heat and glare on hard surfaces, and enhance pedestrian comfort. Trellises and similar exterior structures that can support vegetation may be used to provide shade as well as serve as a visual amenity. Where tree planting is not feasible, use architectural shading devices to incorporate into the landscape and hardscape. Use of deciduous plants will provide shading during summer months and promote desirable solar heat gain during winter months.

The use of shading can also be coupled with other strategies for mitigating heat island effects. Refer to Section 3.4.5 of this Manual for information on the design of hard surfaces to mitigate heat island effects.

3.5 Hard Surfaces

The selection of hardscape (paving) surface materials shall be integrated with the building and landscaping design. Careful consideration should be applied during site planning and site development design to minimize the total footprint of impervious land required for roadways, sidewalks, driveways, and parking areas. Ultimate material selection shall be based on permeability, durability under design traffic load, maintainability, and cost effectiveness. In addition, the following design considerations shall be taken into account:

- **Structural performance.** The design, testing and construction for pavement shall comply with local state highway department standards.

- **Porous materials.** Whereever practical, porous/pervious paving materials shall be used as substitutes for impervious surfaces. Pervious pavement may substitute for conventional pavement on parking areas, walkways, and areas with light traffic. Pervious pavement shall be permitted in areas with gently sloping or flat ground, limited heavy truck use, and where pavements will not receive snow and ice treatments (e.g., salt, sand, chemical). In addition, soils should have permeability rates greater than 0.50 inches per hour, and there should be a four-foot minimum clearance from the bottom of the pavement system to bedrock or the water table. Care should be taken during construction to prevent clogging of porous materials with debris. Porous materials are not recommended for areas that may be susceptible to chemical spills.

EPA facilities pursuing LEED-NC 2009 certification can earn points under the Materials and Resources Category by obtaining paving materials extracted and/or processing in the project vicinity and/or have containing recycled materials (e.g., crushed concrete, tire chips in asphalt). Consult the LEED Reference Guide for specific criteria.

- **Regional materials.** It is recommended that local and regional materials be used to help minimize environmental and transportation impacts.

- **Recycled content**. The use of recycled content is encouraged, where performance is not affected.

Guidelines for specific types of hard surfaces and other considerations are discussed in the following sections. For additional guidance, refer to the Federal Green Construction Guide for Specifiers, 32 12 43 (02795), *Porous Paving* and the EPA 832-F-99-023, *Stormwater Technology Fact Sheet, Porous Pavement*.

3.5.1 Asphalt

Design and construction of asphalt pavement materials shall comply with the local state highway department standards. Where allowable and applicable, porous/pervious asphalt materials and infiltration beds should be used. Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Porous asphalt pavement consists of standard bituminous asphalt, which contains aggregate fines (particles less than 600 µm).

The amount of fines should be reduced to allow water to pass through the asphalt. A bed of uniformly graded, clean-washed stone aggregate with void space of 40 percent should be placed under the pavement; this acts as the infiltration bed or reservoir. Geotextile filter fabric should separate the stone bed from the underlying soil, preventing the movement of fines into the bed, while allowing water to filtrate into the soil and recharge the groundwater. The stone bed is typically 18 to 36 inches deep, depending on the local stormwater requirements, frost depth, and site grading. Two common modifications made in designing porous pavement systems include varying the amount of storage in the course aggregate beneath the pavement and adding perforated pipes near the top of the reservoir to discharge excess stormwater after the infiltration bed/reservoir is saturated and filled.

Care should be taken to consider the proper design factors to increase the performance (and reduce the risk of failure) of porous asphalt. Factors capable of enhancing longevity include proper maintenance, use in low-intensity parking areas, restrictions on use by heavy vehicles, and limited use of de-icing chemicals. For additional guidance, refer to the Asphalt Pavement Alliance website and publications, including *Asphalt: The Sustainable Pavement* and the U.S. Army Corps of Engineers (USACE) Public Works Technical Bulletin 200-1-36, *Sustainable Stormwater Storage Alternatives for Army Installations*.

In addition, the use of recycled tire in asphalt (also referred to as crumb rubber modified asphalt, rubberized asphalt, or asphalt rubber) is recommended. For further guidance, refer to the California Department of Transportation publication, *Asphalt Rubber Usage Guide*.

3.5.2 Concrete

This section covers the design and application of concrete with respect to pavement. Refer to Section 5.3 of this Manual for design criteria for concrete in structural construction. Design and construction of flexible or rigid concrete pavement for parking lots and roadways shall comply with the local state highway department standards. In addition, use of coal fly ash, or other additives, in concrete shall be governed by state building codes.

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.

Where allowable, the use of porous/pervious concrete pavement is encouraged in low traffic areas. Porous concrete is an alternative to porous asphalt, and similarly, can be employed with subsurface infiltration beds while providing stormwater infiltration benefits. However, porous concrete is usually more expensive than asphalt. Porous concrete typically consists of specially formulated mixtures of Portland cement, uniform, open-graded coarse aggregate, and water. Cement-based materials in concrete mix should be 50 percent non-Portland cement pozzolanic materials by weight. For additional guidance, refer to United Facilities Guide Specifications (UFGS) 32 13 13.06, *Pervious Portland Cement Concrete Pavement for Roads and Site Facilities* and the National Ready-Mixed Concrete Association (NRMCA) website, *Pervious Concrete*, as well as other publications by NRMCA.

EPA facilities can earn points toward LEED-NC 2009 certification under the Sustainable Sites category by using porous paving materials that assist in reducing stormwater runoff quantity and improving runoff quality. Specific criteria for earning these points are provided in the LEED Reference Guide.

3.5.3 Pervious Pavers

Where practical, the use of pervious pavers is encouraged in areas that will have low traffic, such as parking lots and walkways. Pavers are pieces and segments of concrete, tile or other material used in exterior hardscaping applications. They are typically interlocking or arranged in a grid pattern and can be referred to as open grid pavement and paver systems. Pervious pavers assist in the management of stormwater runoff by promoting infiltration and groundwater recharge, reducing runoff, and decreasing pollutant loads. Runoff that passes through pervious paving may be:

- Allowed to infiltrate naturally and recharge local groundwater supplies; and/or
- Captured using a subsurface drain system (e.g., French drain) and conveyed to an underground cistern for storage and on-site reuse (e.g., irrigation, flushing toilets, boiler water makeup, etc.).

Examples of pervious pavers are listed below:

- **Concrete Pavers**. These pavers are made to resemble a type of grid, where each paver interlocks into each other. Many concrete pavers have a void or a hole on their surface, where it is possible to fill the paver with more pervious materials like gravel or mulches.
- **Block Pavers.** These can be used to create a porous surface with the aesthetic appeal of brick or other interlocking paving materials. They can be used for driveways, entryways, walkways, or terraces to achieve a formal appearance.
- **Turf/Grass Pavers.** These pavers are made with voids on the pavers, for grass or vegetation to be planted inside and allowed to grow through the paver.

Pervious pavers can also be constructed from natural stone, high strength plastic, or other materials. Concrete grid paver units should comply with ASTM C1319; interlocking concrete paver units should comply with ASTM C936.

3.5.4 Gravel and Other Surfaces

Gravel can be used as a loose fill permeable surfacing, in addition to mulch, brick, natural stone, crushed concrete, and other non-traditional aggregate material. To promote infiltration on the site, gravel and other loose fill permeable surfacing should be employed where practical and in low traffic or landscaped areas. Gravel can be effective as a pervious material, cost effective and relatively easy to install. However, certain types of loose fill surfacing, especially mulches, will require regular maintenance and resurfacing. The following criteria are recommended for gravel and other loose fill permeable surfaces: (1) crushed concrete or blast furnace slag should comply with ASTM D692 (i.e., demonstrate a minimum density as prescribed in the standard); and (2) recycled porcelain or other non-traditional aggregate material should comply with ASTM D6155. Note that slag or other recycled materials may be subject to meeting additional local or regional requirements. Furthermore, a representative sample of blast furnace slag should be tested using the EPA's Synthetic Precipitation Leaching Procedure (SPLP). If the SPLP tests indicate that heavy metals standards for the project site jurisdiction (e.g., state) are exceeded, restrictions on use of blast furnace slag may be required in order to protect groundwater resources.

3.5.5 Heat Island Effect and Mitigation Strategies

Light-colored, high-albedo hardscape materials should be employed to reduce the absorption and radiation of heat. For features such as parking lots, light-traffic roads and walkways, the use of open grid pavement (pervious paving) systems is encouraged to assist with mitigating heat island effects. Other strategies include breaking up large areas of conventional pavement with landscaped islands or open grid pavement, or covering walkways and open areas that are paved with low reflectivity materials. The use of shading can also be coupled with hardscaping strategies for mitigating heat island effects. Design options in addition to vegetative shade include covering structures with solar photovoltaic panels, installing vegetated roofs and/or surfaces with a solar reflectance index (SRI) of at least 29, using paving materials with an SRI of at least 29, and using an open-grid pavement system (e.g. concrete-grass lattice).

3.6 Traffic Control

3.6.1 Roadway Design

Geometric design of all roads, streets, access drives, and parking areas shall comply with local state requirements and AASHTO GDHS guidelines. 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. Signs, pavement markings, channelization, and other traffic control measures shall comply with the standards and requirements set forth in FHWA MUTCD.

Vehicle circulation design should promote logical wayfinding and shall comply with the following requirements and guidelines:

- Vehicle circulation shall be designed in accordance with local code requirements and any overall campus master plan 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.

- Vehicle 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 vehicle circulation. It is preferable for pedestrian access, vehicle access (including parking) and service vehicle access to be segregated.

- 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.

EPA facilities can earn points toward LEED-NC 2009 certification by taking specific measures to reduce the heat island effect. As discussed in detail in the LEED Reference Guide, these measures can involve: (1) partially eliminating hard surface pavements; (2) increasing the reflectance index of pavements and/or roofing materials; and/or (3) installing a "green roof" (refer to Section 4.12.4).

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

- Site design for vehicle movement shall provide adequate space for queueing at drop-offs and exit drives for vehicles ranging from passengar cars to buses and 18-wheel vehicles, 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.

3.6.2 Loading and Unloading Areas

Loading docks must be located for easy access by service vehicles, be separated from the main public entrances to the building, be separated from parking access, and be convenient to freight elevators so that service traffic is segregated from the main passenger elevator lobbies and public corridors. Where possible, a one-way design for service traffic to loading and unloading areas is recommended to avoid the need for truck turning areas.

The following minimum requirements should be applied for loading docks and berths:

- Loading docks must accommodate the vehicles used to deliver or pick up materials from the building. If the bed height of vans and trucks varies more than 18 inches, at least one loading berth must be equipped with a dock leveler. The dock shall be protected with edge guards and dock bumpers. Open loading docks should be covered at least four feet beyond the edge of the platform over the loading berth. In cold climates, dock seals should be used at each loading bay. Alternatively, consideration could be given to enclosing the entire loading bay. Separate or dedicated loading docks should be considered for food service areas. A ramp should be provided from the loading dock down to the truck parking area to facilitate deliveries from small trucks and vans. This ramp should have a maximum slope of 1:12 and comply with ABAAS guidelines, ensuring that deliveries on carts and dollies are maneuverable. If the building size warrants, a dock manager's room or booth should be located so the manager can keep the entire dock area in view and control the entrance and exit from the building. Loading docks must not be used as emergency egress paths from the building.

- The design shall provide at least one off-street berth for loading and unloading. The berth should be 15 feet wide and at least as long as the longest vehicle to be accommodated. Local zoning regulations or the POR may require a longer length. The space should be located adjacent to the enclosed or open loading dock. If additional loading berths are required they need not be wider than 12 feet, as long as they are contiguous to the 15-foot wide berth. An apron space shall be provided in front of the loading berth for vehicle maneuvering equal to the length of the berth plus two feet. This area should be flat, with a minimum slope of 1:50 for drainage. The minimum headroom in the loading berth and apron space is 15 feet. When a steeper slope is required in the apron area, the headroom should increase with a gradient allowance to allow trucks to traverse the grade change. If the approach to the loading dock is ramped, the design should permit easy snow removal.

Fire sprinkler protection in the loading dock area should also be included, in accordance with local and national codes. Additional fire protection specifications are provided in Chapter 9 of this Manual.

A staging area inside the building shall be provided adjacent to the loading dock. It must be protected from the weather. The staging area shall not interfere with emergency egress from the building. Appropriate loading dock/staging facilities are required relative to the size, function, and material requirements of each laboratory. The truck turning radius should be appropriate to the truck size anticipated. A covered loading/unloading area is desirable. The loading dock area shall be considered for video monitoring for security purposes. Additional issues to resolve during the design process are listed in Section 1.4.2, Building Support Zones.

For all facilities, the staging and loading area shall include sufficient space for collection and storage of source-separated recyclables from the various areas of the facility. This area shall be accessible to recycling collection vehicles.

For laboratory facilities, an isolated hazardous materials/waste storage facility shall be also located near the loading area to facilitate transportation and handling of explosive/flammable materials, toxic chemicals, and bio-hazardous waste before disposal at an off-site location by a licensed contractor.

3.6.3 Parking Areas

Parking and its related circulation shall be separated from the service circulation to minimize conflicts. Parking lots and circulation shall meet local governmental standards for circulation, layout, and safety. Accessible parking locations shall comply with ABAAS guidelines. Parking areas should not be located in front of buildings or at visually prominent locations along routes of approach.

In light-traffic areas, concrete curbs and gutters shall be used only when required to control drainage. If possible, minimize the use of curb and gutters in parking areas, and instead, employ the use of pervious pavement and other stormwater management technologies. Removable prefabricated concrete wheel stops may be used where appropriate. Specific parking design guidelines are also presented in Section 3.12 of this Manual.

Any parking spaces above 80 percent of the design capacity shall be located farthest away from the building entrances and shall be constructed from interlocking concrete pavings (pervious pavement) that allow infiltration of stormwater runoff.

3.6.4 Access for Emergency Vehicles

Fire department and emergency vehicle access shall be provided and maintained to all new construction and alterations in accordance with the requirements of NFPA 241, NFPA 1141, and the International Fire Code (IFC).

Design for fire department access should consider vehicular circulation, pedestrian circulation, parking, and any 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).

Local codes, ordinances and fire department requirements must be reviewed to provide adequate access and comply with other specific requirements, such as the surface material of the access roadway(s), minimum width of fire lane(s), minimum turning radius for the largest fire department apparatus, weight of the largest fire department apparatus, and minimum vertical clearance of the largest fire department apparatus. Where there is a conflict, the more stringent guidelines apply.

The following minimum requirements shall be applied for emergency vehicle access design:

- For buildings or portions of buildings exceeding 30 feet in height from the lowest point of fire department access, the site design shall include access roads capable of accomodating fire department aerial apparatuses. Overhead and utility power lines shall not be within the aerial access roadway

- All new buildings shall have at least two sides readily accessible to any fire department apparatus. At least one access road having a minimum unobstructed width of 26 feet shall be located within a minimum of 15 feet and a maximum of 30 feet from the building

- Dead end fire lanes exceeding 150 feet in length shall be provided with an approved area for turning around fire apparatus

- 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

- For the access roadway, the minimum turning radius shall conform to a 53-foot semi-trailer template

- Fire lanes shall be constructed of a grasscrete driving surface capable of supporting imposed loads of at least 25 tons.

- Fire lanes and access areas for fire hydrants, automatic sprinkler, and standpipe connections shall be clearly identified by painting the curbs yellow, with 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

- Site barrier/security systems shall not impede access by emergency vehicles, as described below in Section 3.6.

3.6.5 Pedestrian Walkways

A functional system of pedestrian walkways connecting structures, operational areas, parking areas, streets, and other access paths shall be provided to meet the demands of pedestrian traffic. (Section 202 of the IBC defines pedestrian walkways as walkways used exclusively as a pedestrian traffic way). Pedestrian circulation shall be designed in accordance with industry standards, local/state code requirements, and any overall campus master plan in effect at the site. The location and width of these areas and paths shall be determined in accordance with the site development plan. Walkways shall comply with the most recent ABAAS guidelines, including slopes, landings, and access points. Specific guidelines for the design of pedestrian walkways are prescribed below:

- Pedestrian walkways shall have a minimum of 1 percent cross pitch for drainage and a maximum cross pitch of 2 percent to ensure safe access and use by the physically disabled

- The width of walkways shall be a function of pedestrian traffic volumes determined by the master plan and/or by specific project requirements. However, every sidewalk should be at least 60 inches wide

- Pedestrian walkways should be protected from vehicular traffic to the maximum extent feasible. This can be achieved by providing a six-foot wide, tree-lined buffer between the curb and the outside edge of the sidewalk

- Crosswalks from parking, bus stops, and other buildings shall be clearly marked and properly assigned. Pavement markings and signage shall be consistent and in accordance with standards prescribed in the Federal Highway Administration (FHWA) document, *Manual on Uniform Traffic Control Devices*

- 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

- The transition area from sidewalk to roadway will be equipped with detectable warning surfaces, and will be installed in accordance with FHWA *Designing Sidewalks and Trails for Access, Part II of II,* as well as ABAAS standards

- Pedestrian walkways shall be constructed with non-slip surfaces and be protected from the accumulation of ice to the maximum extent feasible

- Pervious materials should be used wherever possible, except where pedestrian walkways intersect high trafficked areas such as driveways

- Walkways used by occupants to transition between the exit discharge and a public right-of-way shall be a hard surface, able to be shoveled of snow, and unobstructed.

In addition, the project team should consider how to treat the orientation of the building and the site design to encourage use of public transit and to address pedestrian traffic between the building entrance and transit stops.

3.6.6 Bicycle 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. Bicycle access to the site shall be comparable to automobile access. Special attention should be placed on the interaction of vehicular and bicycle traffic flow at facility entrances, and design should account for safety. Signs and pavement markings shall be consistent and in accordance with Part 9 of the *Manual on Uniform Traffic Control Devices.* Ensure that bicycle paths or designated routes to visitor or employee bicycle parking areas avoid sharp turns (e.g., 90 degrees or greater), and are clear of obstructions (e.g., curbs without ramps, parking arms).Secure and covered bicycle parking should be provided at each facility, and bicycle parking should be located such that regular bicycle commuters have easy access to shower facilities that exist at the site. Locate bicycle parking areas as close as possible to the main facility entrance(s). Bicycle parking areas should be placed in a highly visible and illuminated location (i.e., visible from windows or to passersby). Bicycles racks should be installed with minimum clearance from walls, landscaping, and driveways, per the manufacturer's specifications. Recommended racks: (1) support the bicycle with at least two points of contact, (2) minimize the potential for damage by not binding the wheel, and (3) allow the user to lock the frame and at least one wheel. Refer to Sections 3.12.9 and 4.13.10 of this Manual for additional guidance.

EPA facilities can earn one Sustainable Sites point toward LEED-NC 2009 certification if they provide bicycle parking and showers/changing facilities for building occupants. Check the LEED Reference Guide for specific requirements (number of bicycle racks, etc.)

3.7 Site Barrier Systems

This section summarizes Site Barrier System requirements. Refer to Section 2.2 of GSA PBS-P100, and Chapter 2 of the GSA *Site Security Design Guide* for additional guidelines on perimeter security, fencing, and gates.

3.7.1 Fences

Fences can deter both people and vehicles from entering a site, while still maintaining openness and natural surveillance on the site. They can also serve as decorative elements or visually alter and screen the appearance of hardened perimeter elements. The need for perimeter fencing at sites is usually determined by the necessary security level.

Based on requirements for the facility as detailed in the POR, the site may require controlled perimeter fencing and access gates at all driveways/ingress routes. If site perimeter fencing is required, care shall be taken with respect to placement and fabric materials near driveways and site access points in order to avoid problems with sight distance requirements for vehicles entering and leaving the site.

3.7.2 Gates

Gates function as entry control points for vehicles and pedestrians. Where required, gates shall be designed to allow for both adequate entry and security. Remote-controlled, power-operated gates and card readers should be used at all gates where budgets permit. Tamper switches shall protect all equipment. All components shall be designed to be vandal-resistant. When selecting a gate design, consider the building and site design; the gate should be as unobtrusive as possible.

3.7.3 Perimeter Barriers

Physical barriers offer important benefits to a physical security posture. They create a psychological deterrent for anyone thinking of unauthorized entry. They also should delay or (ideally) prevent passage through them, either by forced entry or vehicles.

The perimeter tier of defense should function to protect against two fundamental threats:
(1) penetration by an explosive-laden vehicle (according to facility type and threat level); and
(2) penetration by unauthorized personnel. Available perimeter security measures usually consist of some combination of:

- Physical barriers (e.g., walls, bollards, planters, hardened street furniture, and landscaped earth berms)
- Hardened perimeter entrances for screening both pedestrians and vehicles
- Lighting
- Intrusion detection devices
- Security personnel.

3.7.4 Emergency Vehicle Access

The project architect/engineer and EPA project manager shall coordinate with the local fire marshal or other local authority having jurisdication (AHJ) to meet all relevant requirements of local fire code pertaining to emergency vehicle access. Access to emergency vehicles shall be accounted for in the barrier system design and comply with Section 503 of the IFC and local codes. Gates equipped with electrically controlled devices shall have an override key switch. All electrically controlled gates shall also be provided with a manual override to allow operation of the gate during power outage, and shall be designed to remain in the open position when left unattended. In addition, electrically operated gates shall be equipped with a key switch that meets local code and AHJ's requirements; activation of the switch shall open the gate(s) and cause them to remain in the open position until reset by emergency response personnel.

Bollards installed across entrances that emergency vehicles may use must be collapsible. Bollards shall be designed to collapse when a steady bumper force is provided by an emergency vehicle. In addition, bollards shall be equipped with a manual activation mechanism that can be operated using a standard fire hydrant wrench.

If an intercom system is used at site entrances, it shall allow for emergency response personnel to communicate directly with the facility's Fire Command Center.

3.8 Site Utilities

The site planning investigations and surveys shall determine the availability and location of existing and available utilities such as water, wastewater, electricity, gas, and telecommunications. The conditions of all existing and available site utilities should be reviewed to determine their adequacy as it pertains to requirements imposed by a new or upgraded EPA facility.

While the A/E design contractor is not authorized to make any commitments or negotiate contracts with the local utility service companies or municipal authorities, the A/E design contractor may be responsible for contacting the local utility service providers to determine information such as interest in providing service to the EPA facility, proposed rate structures, and system capacities. Refer to GSA PBS-P100, Section 2.6 for additional guidelines on utility coordination.

If any onsite or offsite utilities require adjustments to facilitate service for the project, the A/E contractor shall furnish recommendations, including load requirements, service characteristics, cost analysis, schematic drawings, and various alternatives for each utility service.

When designing site utility systems, size and terminate utilities to accommodate possible future extensions. If expansion is planned, extend utilities to the edge of the site or to a point where connection can be made without damage or disruption to the utility or adjacent structures. For utilities that can share corridors and piping, establish shared utility corridors to optimize land use and provide adequate utility separation. Ensure that aboveground utility elements such as transformers, generators and backflow prevention devices are located with convenient service access and are integrated with the building and site design.

Except for dense urban areas where there is no feasible alternative, new buildings and structures should not be placed over existing sanitary sewer, water supply, stormwater drainage, electrical, or natural gas lines.

Utilities systems should be located at least 50 feet from loading docks, front entrances and parking areas. Access to utility areas should be restricted to authorized personnel.

In general, advanced metering should be installed for any utility line that would bill at more than ten thousand dollars ($10,000) per year. EPA's advanced metering guidelines are contained in the Appendix AAA of this Manual. Where possible, the number of utility connections per meter should be limited to one per service. In addition, where possible, metering upgrades should be synchronized with the installation of new service lines. Meter upgrades also must be completed in advance of the applicable EPAct and EISA deadlines. New advanced metering systems should tie into existing software and systems used by EPA (e.g., National Advanced Metering Software System).

Guidelines for specific utilities are discussed in the following sections.

3.8.1 Water Supply

3.8.1.1 Potable Water

During design and construction planning, the potable water supply and local/municipal water authority shall be determined. Facilities that obtain drinking water from municipal sources have limited responsibilities for monitoring drinking water, except during initial construction or leasing.

Drinking water in all newly constructed facilities must be tested to confirm compliance with the National Primary Drinking Water Regulations to ensure they do not exceed drinking water action levels. Refer to Chapter 4 of the Environmental Management Manual for sampling requirements.

The design of potable water supply connections shall be coordinated with plumbing design, as detailed in Section 6.13 of this Manual, and shall comply with codes and requirements of the local public water authority. Refer to GSA PBS-P100, Section 5.18, for additional guidance on potable water and plumbing utility design and coordination. Potable water distribution systems shall be included within the utility master plan and shall be metered. In addition, the system should be incorporated into the Building Automation System (BAS), which is discussed in Section 8 of this Manual.

The use of dual water systems (i.e., domestic and industrial or irrigation) or municipal graywater shall be considered but 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 both systems must be clearly identified on the record drawings and by location markers at intervals specified by the EPA project manager.

The planning and routing of the piping system and access points must be determined early in the design process. Water lines shall not be located under foundations and other areas where access is severely limited. During route selection and initial planning for potable 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
- Minimize conflicts with other utilities
- Reduce maintenance requirements

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. Risers from frost line to floorlines of buildings shall be adequately insulated. 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.

Water service meters shall be located inside the building to maintain security and supervision within the security perimeter.

Backflow preventers must be installed on all connections to public or private water supply systems, as specified in Chapter 6, Section 6.10.1 of this Manual.

3.8.1.2 Non-potable Water

Non-potable water is water that does not meet standards for potable water, but is less contaminated than gray water or black water. Examples may include non-contact cooling water, treated effluent from a wastewater pretreatment facility, groundwater removed during dewatering of excavations of uncontaminated soil or fill, condensate from HVAC coils, and (in certain cases) reject water from water treatment systems (e.g., retentate from reverse osmosis systems or backflushing rinsate from sand filters or ion exchange systems). Local codes and standards for non-potable water quality generally will vary based on location. The most-common source of non-potable water will be an on-site operation or process, because public water supplies must meet Safe Drinking Water Act (SDWA) quality standards. The following water streams usually will NOT be classified as non-potable water:

- Water that has come into contact with hazardous wastes or hazardous materials
- Water from car or truck washing operations
- Stormwater runoff, unless it is runoff from a facility that meets the No Exposure criteria in 40 CFR 122(g)
- Direct discharges from laboratory operations that handle chemicals or infectious substances (direct means no pretreatment)
- Decontamination water of any kind that has not been appropriately pretreated
- Boiler blowdown water.

Fire Protection Water

Fire protection water shall be provided in accordance with Section 9.6 of this Manual. For many facilities, fire protection water will be provided from public water supply mains (e.g., municipality, local water authority) that deliver potable water. However, fire protection water does not need to meet potable water standards.

3.8.2 Wells

3.8.2.1 Drinking Water

Where drinking water is derived from on-site wells and is provided to more than 25 individuals or 15 service connections for at least 60 days out of the year, facilities must comply with the requirements for “public drinking water systems” under the Safe Drinking Water Act. These systems are subject to periodic monitoring for physical, chemical, radiological, and biological parameters as specified in Title 40 of the Code of Federal Regulations, Parts 141 and 143 (40 CFR 141, 143). Facilities that obtain drinking water from on-site wells should also be designed with sufficient pretreatment capabilities to ensure the safety and aesthetic quality of the water for general consumption. At a minimum, pretreatment systems for water obtained from on-site sources should provide levels of performance that ensure fulfillment of the primary maximum contaminant levels in 40 CFR Part 141, the lead and copper action levels in 40 CFR 141.80, and the secondary maximum contaminant levels in 40 CFR Part 143.

3.8.2.2 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 calcium carbonate [$CaCO_3$])
- 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.

3.8.3 Hydraulic Design

If LID stormwater strategies and pervious/permeable pavements are employed in the site development design (as discussed in Sections 3.2 and 3.4), conventional stormwater drainage systems should be minimized. However, conventional stormwater drainage methodologies may still be required, such as curb and gutter or retention/detention ponds, as summarized in the following sections. Refer to Section 3.2 of this Manual for guidance on EPA;s required methods for stormwater management, including the requirements of EPA's *Section 438 Technical Guidance*, EPA 841-B-09-001, December 2009.

3.8.3.1 Street Drainage

Where street drainage on paved surfaces is employed, drainage 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 used 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 systems shall have sufficient capacity to ensure that runoff from the 100-year, 6-hour design storm will not exceed a depth of 10.5 inches at any point within the street right-of-way or extend more than 2.5 inches above the top of the curb in urban streets. Inverted crown roadway cross sections shall not be used unless approved by EPA.

3.8.3.2 Parking Areas

As mentioned previously, parking areas for greater than 80 percent of total site capacity shall be paved using pervious pavement systems (the percentage of the total site pavement that is pervious pavement may be increased where approved by the EPA Project Manager). The choice of a pre-cast concrete grid versus a reinforced concrete grid will be made on a site-specific basis, depending on traffic loads. Pervious pavement systems shall be engineered to resist differential settlement and frost heave. Pervious pavement can be integrated with under-drains and underground detention systems for sites where *in situ* soils cannot fully drain the design quantity of runoff or where the facility intends to reuse some or all of the runoff for suitable on-site beneficial uses.

3.8.3.3 Stormwater Retention, Detention, and Reuse

Consistent with EISA, all EPA facilities shall be designed to manage almost all stormwater on site (refer to Section 3.2, which addresses LID and WWGI). However, detention/retention capacity often will need to be provided to manage the excess runoff from severe storms (i.e., those above the 95th percentile storm). Therefore, where necessary, 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. Designers shall consider the use of cisterns to capture roof drainage for onsite use and recycling. Overflow structures capable of managing flow from the 100-year design storm must all be provided with retention/detention ponds. Refer to Section 3.2.3 of this Manual for additional guidance on cisterns and other stormwater collection methods.

3.8.3.4 Subsurface and Open Channel Conveyance Systems

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

- 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.

- 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.

3.8.4 Sanitary Sewer

3.8.4.1 General

The design of sanitary sewer connections shall be coordinated with the facility sanitary sewer design, as detailed in Section 6.13 of this Manual and shall comply with codes and requirements of the local publicly-owned treatment works (POTW) water treatment facility. Refer to GSA PBS-P100, Section 5.18*,* for additional guidance.

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

- Gray water systems should be considered.
- 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 POTW and NPDES as applicable.

Hydraulic design of wastewater collection systems shall comply with local building codes. Additional references include the following:

- ASCE 37-02
- UFC 3-240-07FA
- UFC 3-240-08FA

3.8.4.2 System Routing

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 EPA. 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 EPA for approval.

Sewers and force mains shall have a minimum depth of cover of two 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 is 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 six 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 on each side of the crossing or, the sewer line shall be made of pressure pipe, with no joint located within three feet horizontally of the crossing. Water lines shall, in all cases, cross above sewage force mains or inverted siphons and shall be at least two feet above the sewer main. Joints in the sewer main that are within three 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.

3.8.4.3 Hydraulic and Pipe Design

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 37-02. The following criteria apply:

- Velocities in gravity sewers and force mains shall not exceed 10 feet per second
- Gravity sewers shall be designed for a minimum velocity of two feet per second
- Force mains shall be designed for a minimum velocity of 3.5 feet per second
- The minimum size pipe for a sanitary sewer between manholes is eight inches
- The minimum size pipe for the sanitary building connection is six inches
- The minimum slopes for a six inch sanitary sewer is 0.6 percent
- The minimum slope for an eight inch sanitary sewer is 0.4 percent.

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.

The selection of sewer and force main material shall be based on wastewater characteristics and soil conditions. Inverted siphons using HDPE piping shall be used for sanitary sewer stream crossings. HDPE piping 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 feet or less) under paved surfaces subject to vehicular traffic. Infiltration-exfiltration test requirements shall be specified within the contract documents.

3.8.4.4 Septic Tanks

Septic tank systems shall not be used unless there is no practicable alternative and unless approved by EPA. If these criteria are met, the septic tank system design must include an appropriate effluent disposal system or subsurface wastewater infiltration system and must be permitted by the local/state regulatory authority. Septic tank systems shall not be connected to facility drains other than in lavatories and kitchens.

Generally, septic tanks can be used for facilities with 25 or fewer population equivalents (a population equivalent is considered approximately 100-120 gallons per capita per day). Septic tank systems comprise of wastewater piping, the tank itself, and the effluent leaching system (to a leaching well or leaching drainfield). The septic tank should be underground and made of watertight concrete or fiberglass with an interior liquid depth of at least 42 inches. The minimum size shall be at least 500 gallons. Septic tank design, installation, operation, monitoring and testing shall be subject to local codes and requirements. Refer to the following for additional guidance:

- UFC 3-240-02N
- EPA 625-1-80-012
- EPA 625-R-00-008.

3.8.5 Natural Gas Supply

Gas distribution connections shall comply with federal, state, and local codes and requirements. Natural gas and other liquid fuel gas systems shall comply with NFPA 54/ANSI Z 223.1. EPA shall install metering and advanced metering in accordance with §434 of EISA 2007.

Natural gas piping shall not be run in trenches or other confined/unventilated spaces where leaking gas might collect and cause an explosion or in areas subject to fires. Natural gas piping shall not share the same trench or corridor with other utilities. The minimum horizontal clearance between a natural gas pipe and parallel utility pipe shall be two feet. Do not locate gas piping through other underground structures such as vaults, manholes, or similar underground structures. When connecting to existing live gas mains, connections shall be made in accordance with ASME B31.8.

Natural gas service utility piping entering the building shall be protected from damage by vehicles, foundation settlement, and vibration impacts. Where wall penetration above grade is not possible, the gas pipe shall be within a Schedule 80 black steel, corrosion protected, sealed and vented, gas pipe sleeve that extends from 10 feet upstream of the building wall penetration exterior (or excavation shoring limits if greater) to 12 inches downstream of the building wall penetration. For additional guidance, refer to UFGS 33 51 00.00 20 and GSA PBS-P100, Section 5.18.

3.8.6 Steam from District Energy Systems

District energy systems connect multiple heating and cooling energy users (i.e., buildings) through an underground piping network to energy sources such as central plants, combined heat and power (CHP) sources, and industrial waste or renewable heat sources.

District energy systems are typically located in dense urban settings in larger cities, university campuses, military bases, or airports. The use of district energy and CHP systems to pipe steam to EPA facilities for thermal energy purposes shall be evaluated on a site-specific basis. For project sites that can be connected to a district energy system, the A/E design contractors shall coordinate with the energy source owner/operator to determine capacity and design requirements for the connections and system.

Design shall be coordinated with distributed piping design and distributed power systems as discussed in Section 6.9 and Section 7.8 of this Manual.

For additional information on district energy systems refer to the International District Energy Association Report/White Paper: *The District Energy Industry*, and the EPA publication, *CHP Project Development Handbook*.

EPA's hierarchy for management of condensate produced from DE systems is contained in Section 6.5.1 of this Manual.

3.8.7 Electrical Power

Electrical power connections shall be coordinated with electrical power design, as detailed in Section 7 of this Manual and shall comply with NFPA 70/NEC, as well as local codes and requirements. Refer to GSA PBS-P100, Section 2.6 and Section 6, for additional guidance.

General requirements for electrical power include the following:

- A detailed load study, including connected loads and anticipated maximum demand loads, as well as the estimated size of the largest motor, shall be performed to determine the required capacity of the new electrical service. If the 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.

- The service entrance location for commercial or municipal electrical power shall be determined concurrently with the development of conceptual design space planning documents, and standards for equipment furnished by utility companies shall be incorporated into the concept design. Locations of transformers, vaults, meters and other utility items must be coordinated with the architectural design and must consider both equipment ventilation and equipment removal.

- The routing of other site utilities, electrical power utilities, and the location of manholes and other access points must be determined early in the design process, in coordination with the responsible site civil engineer.

- Cable selection shall be based on all aspects of cable operation and the installation environment, including corrosion, ambient heat, rodent attack, pulling tensions, and seismic activity.

Specific requirements are discussed in the following sections.

3.8.7.1 Overhead Services

Overhead services to buildings should not be used except in circumstances where underground services are not feasible. 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.

3.8.7.2 Underground Services

All underground secondary conductors (voltage less than 600 volts) 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 four 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 NFPA 70. 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.

3.8.7.3 Service Capacity

Incoming transformers must be provided, as required, and must be of sufficient capacity to accommodate the full design load plus 30 percent additional capacity for future growth. 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 NFPA 70 requirements. 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.

3.8.7.4 Metering

Metering and advanced metering should be installed to the maximum extent possible, in accordance with Section 103 of EPAct 2005 and Section 434 of EISA 2007.

Demand metering (kilowatt demand) 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. Sub-metering of lighting and equipment in individual buildings is encouraged to monitor and adjust energy performance. For further guidance on metering requirements and metering specifications, refer to the DOE/FEMP publication, *Guidance for Electric Metering in Federal Buildings,* Section 6.11 and 8.4 and the Appendix AAA of this Manual.

3.8.7.5 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.

3.8.8 Telecommunications, Audio, Video and Data Transmission

The system shall adhere with local code requirements and NFPA 70. Telecommunications utility systems may include telephone, audio, video, and data cabling systems that are provided by local service companies (e.g., digital cable or internet providers). An effective communications cabling system encompasses copper and fiber optic entrance cables, termination equipment, backbone cables, horizontal distribution cables, and workstation outlets.

The A/E contractor shall coordinate with the local telecom company to determine the size, capacity and location of the incoming service as well as the enclosure and pathway requirements for a new system at the facility. Cable selection shall be based on all aspects of cable operation and the installation environment, including corrosion, ambient heat, rodent attack, pulling tensions, and seismic activity.

Cable television (CATV) service shall also be provided to the facility. Typically, CATV service is independent from other communications services.

3.9 Earthwork

Earthwork includes excavation, filling, stabilizing, and compaction of earth at the site. Earthwork also includes the addition of borrow material and the disposal of excavated material. The earthwork design shall incorporate the findings of the geotechnical report. Local topography shall be considered during project and facility design. New facilities shall be planned to fit the local topography and require a minimum amount of grading. It is encouraged to minimize grading overall and to balance cut and fill. Earthwork site plans shall include provisions for erosion control and soil stabilization in ditches, fill slopes, embankments, and denuded areas, as well as restoration of areas disturbed by the project. Restoration shall be to original or improved conditions.

Vegetation and soil protection zones (VSPZs) should be protected in accordance with *Guidance for Federal Agencies on Sustainable Practices for Designed Landscapes*. A soil management plan should also be developed that protects on-site soil from contamination and compaction and establishes soil management and conservation priorities.

In addition, the use of recycled crushed concrete (and other aggregates) is encouraged, where practicable and allowable by local/state regulations. Crushed concrete, in lieu of natural aggregate, can be used in applications such as fill for drainage structures and pavement subbases. For additional guidance, refer to the Portland Cement Association (PCA) publication *Building Green with Concrete*, UFC 3-220-01N and UFC 3-220-03FA.

Recycled concrete would be considered post-consumer recycled material, for the purposes of determining points under the LEED-NC 2009 Materials and Resources Credits. Consult the LEED Reference Guide to determine number of available points based on recycled content.

Specific requirements with respect to different aspects of earthwork are discussed in the following sections.

3.9.1 Equipment and Techniques

It is desirable to balance cut and fill, if the fill can be readily accommodated on the site. Consideration should be given to the use of extra fill material in landscaping berms to avoid extra haul and disposal cost. If large cut and fill volumes are anticipated, the geotechnical report for the project should address shrinkage/swell factors to be used in cut and fill computations.

EPA encourages a sustainable design approach, to first minimize the total amount of grading and then come as close as possible to balancing cut and fill on the site.

3.9.1.1 Excavations

There are two basic types of excavations: “open excavations” where stability is achieved by providing stable side slopes and “braced excavations” where vertical or sloped sides are maintained with protective structural systems that can be restrained laterally by internal or external structural elements.

In selecting and designing the earthwork and excavation system, the primary controlling factors include soil type and soil strength parameters, groundwater conditions, slope protection, side and bottom stability, vertical and lateral movements of adjacent areas, and effects on existing structures.

3.9.1.2 Fill

Fills include conventional compacted fills; hydraulic fills; and uncontrolled fills of soils or industrial and domestic wastes, such as ashes, slag, chemical wastes, building rubble, and refuse. Properly placed compacted fill will be more rigid and uniform and have greater strength than most natural soils. Hydraulic fills may be compacted or uncompacted and are an economical means of providing fill over large areas. Except when cohesionless materials, i.e., clean sands and gravels, are placed under controlled conditions (so silty pockets are avoided and are compacted as they are placed), hydraulic fills will generally require some type of stabilization to ensure adequate foundations. Uncontrolled fills are likely to provide a variable bearing capacity and result in a non-uniform settlement. They may contain injurious chemicals and, in some instances, may be chemically active and generate gases that must be conducted away from the structure. Subject foundations on fills of the second and third groups (and the first group if not adequately compacted) to detailed investigations to determine their suitability for supporting a structure, or else they should be avoided. Unsuitable fills often can be adequately stabilized.

Foundations can be designed on the basis of bearing capacity and settlement calculations. The settlement and bearing capacity of underlying foundation soils also should be evaluated. Most types of construction can be founded on compacted fills, provided the structure is designed to tolerate anticipated settlements and the fill is properly placed and compacted.

3.9.2 Excavation Safety

- In the course of conducting all project activities, not limited to excavation, all applicable regulatory requirements of 29 CFR 1910 and 1926 will be met or exceeded. In the course of carrying out excavation activities the following best practices will be utilized in addition to the requirements of applicable OSHA Standards (including 29 CFR 1926 Subpart P – Excavations):Open Excavations Techniques with one to one benched sloping will be used whenever possible. Braced Excavation techniques will be used only where Open Excavation with one to one sloping is not possible due to proximity to structures etc.

- Excavation will be planned and executed in a manner to avoid the need for personnel to enter excavations.

- Excavations spoils hsall be placed no closer to the edge of the excavation than one excavation depth away.

- No personnel will work adjacent to any excavation until a reasonable examination of the same has been made to determine that no conditions exist exposing them to injury from moving ground

- Trees, boulders, and othr surface encumbrances that pose at any time during operaton a hazard to employees involved in excavation, or in the vicinity thereof, will be removed or made safe before excavation is begun.

- Before any excavation work, the existance and undergurnd pipe, electrical conductors, underground structures, etc., must be determined.

- At any time that entry into an excavation is required, a standby person shall be available. Any person entering the excavation shall wear a lifeline and harness in addition to any other required personal protective equipment.

- Excavations shall be inspected by a Qualified Person after every rainstorm or other hazard-increasing occurance, and the protection against slides and cave-ins will be increased if necessary.Appropriate access methods, such as ladders shall be used to enter the excavation. Trenches more than 4-feet deep shall have ladders or steps that require no more than 25 feet of lateral travel between means of access/egress.

- Under no circumstances are personnel allowed to ride backhoe buckets etc. especially in order to enter or leave an excavation.

- All equipment, such as pipe, rebar, etc. shall be kept out of traffic lanes and access ways. Equipment shall be stored so as not to endanger personnel or negatively impact the excavation.

- All excavations shall be backfilled as soon as prctical after work is completed and all associated equipment removed from the area

- All excavations shall be adequately defined to prevent personnel or equipment from inadvertantly falling in. Protection not limited to signs, fencing, rope, warning tape, and barricades will be used as necessary.

- Excavations that shall remain open overnight shall be protected so that no personnel or equipment could enter without going through a physical barrier (rope, barricade, or fencing) in addtion to warning signs or tape.

- Provisions shall be made to prevent ground personnel or equipment from entering the area defined by the potential movement of backhoes' articulating arm and bucket or similar excavation equipment in the performance of their work activities.

- Site personnel shall be trained to make eye contact and use hand signals to effectively communicate with equipment operators. Personnel shall not enter the potential swing or movement zone of excavation equipment until receiving clear recognition and permission of the equipment operator.

3.9.3 Disposal of Contaminated Soil

The A/E construction contractor shall be responsible for the removal of excavated and/or contaminated soils. All construction materials removed from the property, including surplus or unsuitable soils, shall be properly disposed of at a legally approved site, and all removal shall be in accordance with all applicable federal, state, and local regulations.

Excavated soil that is also identified as contaminated shall be segregated from all other excavated soils, and shall be stockpiled on site on two polyethylene sheets with a polyethylene cover. A designated area shall be selected for this purpose. The contaminated soil shall be disposed or treated, in accordance with state and local requirements.

3.9.4 Materials Specifications

All proposed fill material shall be evaluated, specified and approved by a licensed geotechnical engineer. Excavated materials may also be used if approved. Evaluation of backfill materials consists of exploration, sampling, and laboratory testing to determine the engineering characteristics of potential backfill materials.

Soils shall be classified based on the Unified Soil Classification System (ASTM D2488), which identifies a soil based on grain size distribution and plasticity and categorizes with respect to the soil's distinctive engineering properties. Refer to Section 3.8.5 of this Manual for additional guidance on geotechnical testing requirements.

3.9.5 Geotechnical Testing

For most projects, geotechnical testing will need to take place at three stages: site selection (i.e., the pre-development geotechnical and subsurface investigation), building design, and construction.

During the building design phase, geotechnical testing shall be conducted to determine the character and physical properties of soil at the site, to evaluate their potential as foundations for the project or as material for earthwork construction. The geotechnical investigation and testing shall address recommendations for lift thickness, required compaction and moisture content for fill, subgrade, and sub-base materials, as appropriate for the specific project and site. Compaction requirements should reference industry standard density testing procedures (e.g., ASTM D698 or ASTM D1557, and/or the relevant state department of transportation standards).

Testing and sampling shall comply with ASTM D1586, ASTM D1587, and ASTM D2113. 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 EPA Project Architect/Engineer and/or A/E design contractor on site-related design requirements.

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 D2488, 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.

3.10 Foundations

3.10.1 Structural Considerations

The foundation design shall proceed on the basis of the approved geotechnical report and shall be performed by a licensed professional engineer.

The selection of an appropriate foundation depends on the structure function, soil and groundwater conditions, and other factors. For all structures, the requirements of standard design criteria and accepted engineering practices shall be met with respect to determining subsurface conditions, recommending foundation type, establishing allowable soil-bearing pressure, determining seismic potential, differential settlement, and static/dynamic loads of the facility. The potential adverse effects of frost heave and movements due to expansive soils shall also be considered in the design. Heavy, vibration producing equipment, such as chillers, fire pumps, engine/generator sets and high-pressure air compressors, should have separate isolated foundations.

Structural considerations for foundations should be fully coordinated and integrated with the structural design of the building, and structural analysis and design shall be conducted by a licensed professional engineer. The provisions of the local governing building code shall be the minimum requirements for foundation design.

The recommended foundation type, allowable bearing pressure, foundation depth, expansive/settlement parameters, and other designs shall be included in a Foundation Design Analysis (FDA). The FDA should also indicate whether slab-on-grade first floors may be used or whether first floors must be structurally supported over a void due to expansive soil conditions. The foundation type and design must satisfy the limiting deflections required to ensure proper performance of the building superstructure. Differential settlements/heave should be limited to L/600-L/1000, L/360-L/600 and L/200-L/360 for rigid, semi-rigid and flexible framing/wall systems, respectively; where L is the distance between points in question. Allowable foundation bearing pressures should be given in the FDA and are normally given as net values, intended for use with service loads consisting of dead loads plus that portion of live loads that act continuously.

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.

The structural design drawings shall indicate the following: 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. Specific requirements for foundation design and construction are discussed in the following sections.

Refer to the following for additional guidance:

- UFC 3-220-01N
- UFC 3-220-03FA
- UFC 3-310-02A

3.10.2 Foundation and Concrete Work Safety

In the course of conductin all project activities, not limited to foundation and concrete work, all applicable sections of 29 CFR 1910 and 1926 will be met or exceeded. The A/E and construction contractor shall plan and implement safety precautions during construction of foundations to protect workers on site. Also refer to Section 3.8.2 of this Manual for guidance on safety requirements related to excavation. In the course of carrying out all foundation and concrete work the following best practices will be utilized in addition to the requirements of applicable OSHA standards (including 29 CFR 1926 Subpart Q – Concrete and Masonry Construction):

- Personnel are not to enter the confined spaces of concrete form work without full compliance with the 29 CFR 1910 and 1926 requirement for this type of work. A structural engineer must also inspect and approve formwork for structureal soundness prior to any personnel entry.

- All horizontal and vertical rebar impailment hazards are to be eliminated through any effective means available (not limited to rebar caps

- Personnel working with concrete, cement, and mortar will be provided with gloves, boots and other personal protective equipment to limit their direct skin exposure to these materials.

- Positive, effective, and reliable methods will be utilized to prevent the potential of employee engulfment hazards during concrete pouring.

- Barricading will be provided to keep nonessential personnel at a safe distance from concrete form work during pouring and prior to initial setting occurring. A safe distance is that which will prevent potential injury in the event of form failure.

- Employees performing concrete and masonary work will be fully trained to perform their work in a safe and efficient manner. Personal protective equipment, ladders, fall protection, scaffolding, overhead protection, etc. will be inspected on a daily basis to ensure their serviceable condition. Inspections will be conducted by qualified personnel and any structure or device not meeting minimal requirements will be immediately repaired or replaced.

- Any concrete or masonary finishing will operatons will provide for the occupationa health protection of all potentially exposed personnel. This includes but is not limited to consideration of silica, hexavalent chromium, asbestos form fibers, cement dust, total dust, etc. Effective dust control will be used as necessary to control dust at the tool – media interface. Airborn concrete and masonary dust plumes are not to be generated or allowed to leave the immediate work area.

- Concrete delivery trucks will utilize a preplanned path for entering, delivering concrete, and leaving the site. This planning is to include the selection of a safe and stable path for travel and to work from during delivery. This may include site preparation not limited to building temporary roads or constructing a stable work platform for delivery operations. Concrete delivery trucks will have their on site activity directed by a groundsman provided by the construction contractor. The path for access and egress as well as the location for delivery will be kept clear of non-essential personnel by whatever means necessary.

3.10.3 Slab-on-Grade

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 (vapor barrier/retarder) should be used under the slab, where moisture conditions warrant (refer to Section 3.11 of this Manual for guidance on vapor barriers). Excess loads, or equipment subject to vibration, shall be supported by separate pads isolated from the rest of the floor slab with flexible joints. In addition, the slab-on-grade should be properly insulated to save energy and reduce heat loss.

Slabs-on-grade will be designed for bending stresses due to uniform loads and concentrated loads and for in-plane stresses due to drying shrinkage and subgrade drag resistance. Slabs are required to have a minimum thickness of four inches. The following thickness for maximum uniform design live loads will be used, provided the modulus of subgrade reaction (k) is at least 100 pounds per cubic inch:

Table 3-1. Slab Thickness for Maximum Uniform Design Live Load

Thickness of Slab (inches [in])	Maximum Uniform Design Live Load (pounds/square foot [psf])
4 in	150
5 in	250
6 in	400

Source: UFC 3-310-02A, Section 5.2

Design should conform to ACI 302.1. Refer to UFC 3-310-02A for additional guidance. Unless otherwise specified above, the correct slab thickness will be determined in accordance with the PCA publication, *Slab Thickness Design for Industrial Concrete Floors on Grade*. In the PCA design process, compressive strength is converted to modulus of rupture, which is then reduced by a factor of safety to obtain the maximum allowable flexural tensile stress. The maximum allowable flexural tensile stress is then used to find the required slab thickness. For typical values of modulus of subgrade reaction refer to UFC 3-320-06A. When wall loads exceed 300 psf slabs-on grade will be thickened in accordance with the provisions of UFC 3-320-06A.

3.10.4 Spread Footings

Spread footings, also referred to as continuous spread footings, are used to provide a stable base around the entire perimeter of a structure. Footings shall not bear on soft or uncompacted soils, nor be located in zones of high volume change due to moisture fluctuations. The following criteria apply for foundation footings:

- Footings shall be designed so that the allowable bearing capacity of the soil is not exceeded and differential settlement is minimized. The minimum width of footings shall be 12 inches. Footing design shall be in accordance with ACI 318.

- Where a building is assigned to Seismic Design Category D, E, or F, as defined by FEMA 302, NEHRP: *Recommended Provisions for the Seismic Design of New Buildings and Other Structures*, individual spread footings founded on soil should be interconnected by ties in accordance with the provisions of FEMA 302 and UFC 3-310-04.

- When gable bent frames are anchored to the slab-on-grade it is imperative that the location of the ties be coordinated with the slab-on-grade jointing to ensure tie capacity is not reduced or impaired by the joints. Reinforced concrete tension tie beams are required for gable bent frames with spans of 50 feet or more.

- Expansive soils change volume from changes in water content leading to total and differential foundation movements. Seasonal wetting and drying cycles cause soil movements that may lead to long-term deterioration of structures. Estimates of the potential heave of expansive soils are necessary for consideration of the foundation and footing design.

3.10.5 Piers and Caissons

Pier/caisson foundations are constructed by digging, drilling, or otherwise excavating a hole in the soil, which is subsequently filled with plain or reinforced concrete. Steel casings may or may not be used to facilitate pier construction. Two pier foundation types common to building construction, augured uncased piers or drilled shaft piers, along with their advantages and disadvantages are described below. The design of pier foundations will follow the recommendations contained in ACI Committee Report 336. In addition, inspectors familiar with pile and pier construction will be present when pile or pier foundations are being installed, and during load testing.

- **Augured Uncased Piers**. Augured uncased pier foundations are constructed by depositing concrete into an uncased augured hole. The drill hole diameter can range from 10 to 72-inches, and up to 200 feet deep. In advancing through granular materials, drilling mud is often required to keep the hole open. The drilled shaft is filled with concrete in the dry, or by means of a tremie pipe through the drilling mud. When the concrete is to be reinforced, care and planning is required to ensure the reinforcement can be placed in the desired location and to the depth required. For drilled piers installed with a hollow stem auger, where longitudinal steel reinforcement is placed without lateral ties, the reinforcement will be placed through ducts in the auger prior to the placement of concrete. When transverse reinforcement is required, the reinforcement is fabricated in cages which are securely tied so they will not rack or otherwise distort when handled and placed in the augured hole. Transverse confinement reinforcing similar to that indicated for prestressed piling is required for uncased concrete piers constructed in high seismic areas.

- **Drilled Shaft Piers**. Drilled shaft piers can be generalized as large diameter cast-in-place concrete filled pipes. Pier diameter range from 12 to 36 inches, and the casing may, or may not remain part of the load-carrying element. Casings where used are usually thick-walled. Drilled shaft piers can be designed to carry extremely heavy loads to extreme depths. Once installed to the desired depth, the pipe is cleaned, reinforcement placed, and filled with concrete if dry, or filled by the tremie method if water is present. The pipe can then either be pulled for reuse, or left in place to increase load carrying capacity. Transverse confinement reinforcing, similar to that indicated for prestressed piling, is required for caisson piers constructed in high seismic areas in those cases where the pipe is to be pulled. When the pipe is left in place, the pipe can be used to provide the necessary concrete confinement.

3.10.6 Frost Protection

The foundation design shall also incorporate frost protection, with consideration for the climate and location (i.e., non-frost, seasonal frost or permafrost). Note that design may be the same as for non-frost regions, using conventional foundations, for areas that have clean sands and gravels at the maximum depth of seasonal frost penetration.

The minimum design depth of building foundations to protect against frost penetration will be in accordance with UFC 3-310-01. The minimum suggested depth when not governed by frost protection requirements will be 12 inches.

In colder regions with the potential for frost heave (but not with a mean annual temperature less than 32°Fahrenheit [F]) and where allowable based upon local codes, consider the use of frost protected shallow foundations (FPSF). A FPSF design incorporates strategically placed insulation to raise soil temperature and the frost depth around a building, thereby allowing foundation depths as shallow as 16 inches. Thermal insulation may be used in foundation construction, in both seasonal frost and permafrost areas, in order to control frost penetration, frost heave, and condensation, and to conserve energy, provide comfort, and enhance the effectiveness of foundation ventilation. Refer to Section 11 of UFC 3-220-01N, and ASCE 32-01 for additional guidance on foundation design with respect to frost penetration and protection.

3.10.7 Shoring and Underpinning

Remedial shoring and 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.

3.10.8 Structural Resistance to Natural Forces and Disasters

The quality of materials used in construction and the quality of construction are important safety factors, which can determine whether a building will survive extreme loadings due to earthquakes or wind. Testing and inspection programs are necessary to ensure the finished structure meets code requirements. It is the designer's responsibility to ensure all testing and special inspections required by code are part of the contract documents. It is expected that the building design and construction will be consistent with the requirements for sismic activity, common weather paterns, flood events, etc.for the area where the building construction will take place. Safety considerations as required by OSHA shall be followed for design, planning and construction. Refer to Section 3.8.2 of this Manual for guidance on OSHA safety requirements.

3.10.9 Use of Fly Ash and Recovered Mineral Additives

The use of fly ash or other recovered mineral additives (i.e., supplementary cementitious materials [SCMs]) is encouraged (EPAct 2005, Section 108) for building foundations and other concrete components, where performance or structural integrity is not affected. Refer to Section 5.3 of this Manual for additional guidance on using SCMs in concrete. The allowable percentage of coal fly ash, or any additives, in concrete shall be governed by state building codes and ASTM C618. Other SCMs such as pozzolans, and ground-granulated blast furnace slag (ASTM C989) may be used. Testing of materials through trial batching is strongly recommended so that properties that are important to performance (e.g., setting time, rate of strength development, porosity, and permeability, among others) can be determined.

Fly ash with total pozzolanic content below 50 percent is considered inappropriate for construction use. Because fly ash comes from various operations in different regions, its mineral makeup may not be consistent; this may cause its properties to vary, depending on the quality control of the manufacturer. There are some concerns about freeze/thaw performance and a tendency to effloresce, especially when used as a complete replacement for Portland cement. In general, fly ash that is high in pozzolanic materials (e.g., silicon, aluminum, and iron oxides) is desirable, because the pozzolanic material will react with excess lime to form additional cementitious material, which - when it cures fully - can increase the ultimate strength of the concrete. Refer to the Coal Ash Resources Research Consortium publications and websites for additional information.

3.11 Dewatering

Dewatering is the removal and control of groundwater or surface water from a construction site to allow construction to be done in dry conditions. Proper dewatering techniques will filter water of sediment, oils, and other chemicals, thus preventing these pollutants from entering the surface waters.

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 UFC 3-220-05. Field reports identifying groundwater elevations and other relevant features should be provided to the construction contractor responsible for dewatering and groundwater investigation. The groundwater investigation and the selection and design of a dewatering control system shall comply with UFC 3-220-05.

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 design engineer shall determine whether the assistance of a qualified groundwater hydrologist shall be required.

3.11.1 Groundwater Control

Subsurface construction should not be attempted without appropriate control of groundwater and hydrostatic pressure. The design, installation, and operation of dewatering systems for groundwater control shall be the responsibility of the A/E design and/or construction contractor and the design should comply with the guidelines set forth in UFC 3-220-01N and UFC 3-220-05. The groundwater investigation and the selection and design of a dewatering control system shall consider recharge beds and retention basins. The design engineer shall determine whether the assistance of a qualified groundwater hydrologist shall be required.

3.11.2 Systems and Technologies

Dewatering is typically employed in areas that have high ground water tables, or which do not have adequate drainage. Dewatering and groundwater control techniques can be applied for the following purposes: excavations that require drainage, seepage control, seepage cutoffs; control of surface waters; sheet pile cofferdams; and foundation underdrainage and waterproofing. The design engineer shall determine the proper excavation system and technologies to employ, specific to the site conditions.

3.11.3 Treatment/Disposal of Groundwater

Local/state governments and NPDES permitting authorities will likely have applicable permitting requirements for discharges to local stormwater drainage systems or surface waters that result from dewatering construction operations. Many local/state governments include minimum treatment, sediment removal and BMP requirements, which are generally required to be outlined in stormwater management and/or erosion control plans.

The construction contractor shall provide for the proper collection, treatment and disposal of groundwater encountered during construction dewatering, as well as complete the appropriate permitting requirements, in accordance with local/state requirements.

3.12 Vapor Barriers

3.12.1 Applications

A vapor barrier (or vapor retarder, vapor diffusion retarder) restricts the movement of water vapor through a material. Vapor barriers can help control moisture and are typically employed in the following areas: basements, ceilings, crawl spaces, floors, slab-on-grade foundations, and walls. Effective moisture control in these areas includes sealing gaps in the structure in addition to the use of a vapor barrier.

The ability of a material to retard the diffusion of water vapor is measured by permeability units known as "perms" (measured in nanograms per Pascal [Pa]-second-square meter). The application of a vapor barrier is dependent upon the local climate. Typically, the number of Heating Degree Days (HDDs) in an area is used to help make these determinations. An HDD is a unit that measures how often outdoor daily dry-bulb temperatures fall below an assumed base, normally 65°F. In addition, a project and climate-specific moisture analysis should be conducted to determine the need for a vapor barrier and the required maximum permeability-to-water value(s).

Note that some codes and guidance materials differentiate the terms “vapor diffusion retarder”, “vapor retarder” and “vapor barrier”, while some use them interchangeably. Some specify that retarders slow down the movement of moisture and that barriers completely stop the movement of water vapor. For the purposes of this manual, when the term “vapor barrier” is used, it is also inclusive of other types of vapor retarders.

3.12.2 Construction Best Practices

General guidelines for placing vapor barriers include the following:

- In climates with 2,200 or more HDDs, locate the vapor barriers on the warm side of the exterior structural assembly. If possible, locate it on the inside of the assembly using the "one-third, two-thirds rule": the vapor barrier has one-third of the cavity insulation to its warm side, two-thirds to the cold side. This protects the vapor barrier from physical damage through errant construction or remodeling activities.

- In climates with fewer than 2,200 HDDs (cooling-dominated climates) and where the building is near, but not quite in, the 2,200 HDDs zone (also known as the fringe zone), place the vapor barrier in the same location as climates farther north.

- In climates with about 1,900 HDDs, it is unimportant where the vapor barrier goes. For climates even farther south and generally hotter and more humid, some professionals recommend omitting the vapor barrier completely. This is due to the winter heating loads and summer cooling loads being roughly equal. A combination air barrier/vapor diffusion retarder may be a better choice for this situation.

In general, a material with a permeability rating of less than one is considered a vapor barrier/vapor diffusion retarder. However, if the warm-side vapor diffusion retarder and interior finish is carefully sealed, a low-permeable material can also be safely installed, such as rigid foam board insulation (a perm rating as high as 1.4), on the cold side of walls. To prevent trapping any moisture in a cavity, the cold-side material's perm rating should be at least five times greater than the value of the warm-side. Use a vapor diffusion retarder with a perm value of less than 0.50 if the site also has a high water table.

A vapor barrier is only effective if it is properly selected and properly installed. When installing a vapor barrier, it should be continuous as possible. Any tears, openings, or punctures that may occur during construction should be completely sealed. Cover all appropriate surfaces, and seal at sill, header, windows, doors and utility penetrations. Do not install vapor barrier on both sides of insulation. Do not utilize polyethylene membrane and other combustible membranes as vapor barriers where they will be exposed to occupied or accessible areas. Such vapor barriers must be covered to provide fire safety as required by applicable building codes. For additional guidance, refer to the following:

- ACI 302.2R-06

- ACI 302.1R-96, *Addendum*

- DOE, *Consumer's Guide to Energy Efficiency and Renewable Energy, Vapor Barriers* (website)
- UFC 3-440-05N
- UFGS 07-21-23.

3.12.3 Materials of Construction

Vapor barriers are typically available as membranes or coatings. Membranes are thin, flexible materials, but may include thicker sheet materials sometimes called "structural" barriers. Materials such as rigid foam insulation, reinforced plastics, aluminum, and stainless steel are relatively resistant to water vapor diffusion. These types of vapor barriers are usually mechanically fastened and sealed at the joints. Other materials include polyethylene or rubber membranes.

The thinner membranes come in rolls or as integral parts of building materials, such as aluminum- or paper-faced fiberglass roll insulation or foil-backed wallboard. Polyethylene (plastic sheeting) can be used as a vapor barrier for above-grade walls and ceilings only in very cold climates (in locations with 8,000 HDDs or higher).

Most paint-like coatings also retard vapor diffusion. Vapor retardant finishes labeled by manufacturers as having a water vapor permeance of no more than the required value can be used. Alternate materials include paints, vinyl wall coverings, or foil-faced gypsum board.

If the perm rating of the paint is not indicated on the label, use the paint formula to ascertain the percent of pigment. To be effective as a vapor retarder, it should consist of a relatively high percent of solids and thickness in application. Glossy paints are generally more effective vapor diffusion retarders than flat paints, and acrylic paints are generally better than latex paints.

3.12.4 Foundation Vapor Barriers

Foundation or under-slab vapor barriers are used to control ground moisture from making its way into the structure. These are usually located between a drainage system under the foundation and the foundation itself, as well as between concrete joints, and between the foundation and the structure. Foundation vapor barriers protect the structure from mass leakage as well as leakage due to capillary action through the concrete. This method not only protects the structure from leakage, mold, and mildew, but also inhibits structural damage do to foundation degradation and heat loss through the concrete. Foundation vapor barriers may include polyethylene sheets, asphalt/polyethylene composite sheets or polymer modified bitumen sheets. The most commonly used vapor retarder is two layers of six millimeter polyethylene sheets, as two layers can be used to reduce puncturing and provide redundancy at seams.

If the use of a foundation vapor barrier is required, the decision on whether to locate it in direct contact with the slab or beneath a layer of granular fill should be made on a case-by-case basis. Refer to *ACI 302.2R-06*. In addition, *ACI 302.1R-96 Addendum* summarizes a decision-making process with respect to where a foundation vapor barrier should be placed, as shown in Figure 3-1.

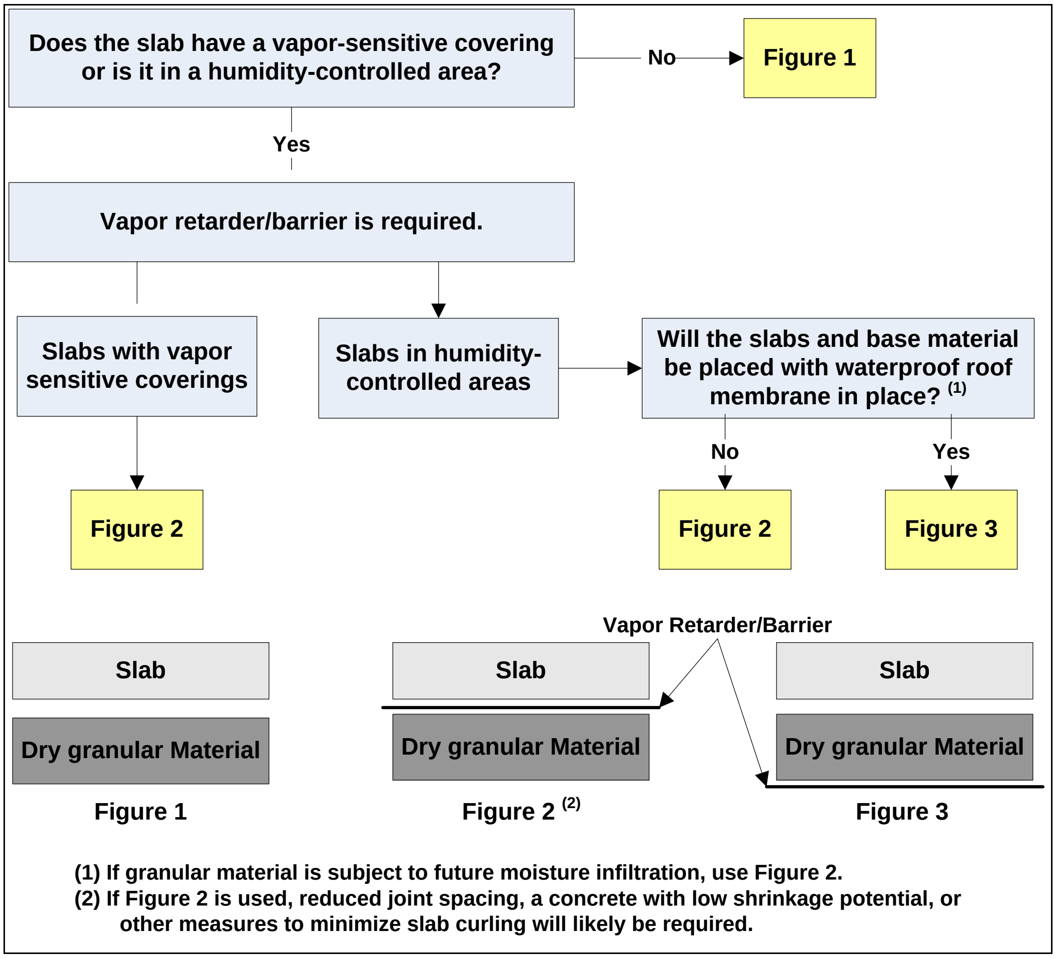

Figure 3-1. Flow Chart for Determining the Location of Vapor Retarder/Barrier
Source: ACI 302.1R-96 Addendum: Vapor Retarder Location

When specifying a vapor barrier designed for use in under concrete slab applications, ensure that the supplier meets the newest and most stringent ASTM standard, E1745. This should ensure minimum values are met regarding tensile strength and puncture resistance, along with maximum allowable water vapor permeability.

3.13 Parking

3.13.1 Parking Standards

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 possible, size parking capacity not to exceed minimum local zoning requirements. The structural design for pavement on surface lots shall comply with local/state highway department standards for general parking areas.

Accessible parking locations shall comply with ABAAS guidelines. Accessible parking shall be located on the shortest accessible route of travel from adjacent parking to an accessible entrance. Accessible parking spaces shall be at least 96 inches wide. Parking access aisles shall be part of an accessible route to the building or facility entrance. Two accessible parking spaces may share a common access aisle.

At a minimum, the following guidelines shall be followed:

- Parking capacity shall be determinated based on the maximum occupancy of the building. Thus, capacity calculations may need to be revised at different points in time during the building's operating life.

- 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 must be nine feet wide and 18.5 feet long, with two way aisles of 24 feet. Where possible, 90 degree parking should be used.

- Up to 15 percent of the parking may be designated for compact cars. Stalls for compact cars shall be at least eight feet by 18 feet.

- Wheel stops should be provided around the parking lot perimeter. It is encouraged to incorporate pervious pavement in the parking lots and minimize or eliminate usage of curbs and gutters.

- Dead-end parking bays are not allowed.

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

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

As part of the site planning and site development design, parking garages or below-ground parking shall be considered as an alternative to surface parking. The following guidelines shall be followed with respect to pavement design and pertinent stormwater management requirements (refer to Section 3.2.2):

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

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

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

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

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

EPA facilities that provide a certain percentage of preferred parking spaces for low-emitting and fuel-efficient vehicles and/or fueling stations for alternative fuel vehicles may earn up to three points toward LEED-NC 2009 certification. In addition, facilities that restrict parking capacity per occupant (thus encouraging non-automobile means of transport) may earn up to two points. Specific criteria are contained in the LEED Reference Guide.

Where feasible, pervious pavement shall be specified and installed as discussed previously in Section 3.5.3. As noted in Section 3.12.1 below, for overflow parking areas, at least 20 percent of such areas shall be constructed from pervious paving components/materials.

In communities working to create mixed-use, compact, and walkable places, inflexible application of conventional minimum parking requirements tends to create an oversupply of parking. This encourages dependency on automobiles and creates unnecessary environmental impacts and financial costs. Fewer residents, workers, and shoppers require parking in areas with public transit service. Policies and programs to reduce dependency on automobiles can reduce the demand for parking, which in turn reduces impervious surface area, stormwater, and the heat sink effect associated with large, open expanses of asphalt. In general, parking designs should:

- Encourage and reward carpooling, public transit use, and bicycle commuting
- Seek opportunities for shared parking. This is based on the concept that different destinations attract customers, workers, and visitors during different times of the day
- Identify existing centralized parking facilities. These facilities can support urban design goals, if they eliminate the need for numerous surface lots that interrupt the walkable fabric of mixed-use areas
- Land banking. Set aside adjacent surface area as a designed overflow when parking requirements increase for specific events, or if parking demand increases over time.

3.13.2 Internal Parking

For parking facilities inside the building, it is recommended that public/visitor parking be accommodated only if incorporated with an identification check by security personnel, particularly if the facility risk or security level necessitates an enhanced level of security. Parking inside of a building may include EPA-owned vehicles and employee vehicles.

To aid in mitigating the urban heat island effect, EPA facilities can earn one point toward LEED-NC 2009 certification by (among other requirements) locating 50 percent or more of the site's parking spaces underground or under roof. Specific requirements can be found in the LEED Reference Guide.

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 two hours.

3.13.3 Structured Parking

The construction, protection, and control of hazards in parking structures shall comply with the requirements of NFPA 88A. Entrances between garages and elevators shall be protected by a vestibule having a 1.5-hour or higher fire door. Doorways between garages and stairs, building corridors, or other non-garage areas shall be protected by 1.5-hour 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.

3.13.4 Natural Surveillance

For stand-alone, above ground parking facilities, the design should maximize visibility across, into and out of the parking facility, in order to promote natural surveillance. Long span construction and high ceilings create an effect of openness and aid in lighting the facility. Shear walls should be avoided, especially near turning bays and pedestrian travel paths. Where shear walls are required, large holes in shear walls can help to improve visibility. Openness to the exterior should be maximized. It is also important to eliminate dead-end parking areas, as well as nooks and crannies. Landscaping on the exterior of the facility should not provide hiding places for trespassers and should permit observation of trespassers.

EPA facilities can earn one point toward LEED-NC 2009 certification if a certain number of preferred parking spaces are provided for low-emitting and alternative fuel vehicles (e.g., hybrids). Construction and operation of an alternative fuel refueling station on the project site is another strategy for earning this point. See the LEED Reference Guide for specific requirements.

The parking facility design should employ express or non-parking ramps, directing the user to park on flat surfaces. Pedestrian paths should be planned to concentrate activity to the extent possible. For example, bringing all pedestrians through one portal rather than allowing them to disperse to numerous access points improves personal security and reduces the number of potential pedestrian-vehicle conflict points. Likewise, limiting vehicular entry/exits to a minimum number of locations is preferred.

3.13.5 Perimeter Access Control

For buildings equipped with a parking facility, the parking facility shall be enclosed and equipped with a perimeter sensor system and gates. The gates shall be equipped with a computerized access control system, and EPA card readers shall be installed at access points. If the POR design and/or security level necessitates, a guard gate should be utilized at the facility's parking entrance to enable perimeter vehicle inspection. Refer to Section 2.6, Section 3.6 and Section 4.14 of this Manual for additional design criteria on physical security measures with respect to vehicle and building entrances.

3.13.6 Surface Finishes and Signage

Interior walls of parking structures should be painted a light color (i.e., white or light blue) to improve illumination. Signage should be clear to avoid confusion and direct users to their destination efficiently. If an escort service is available, signs should inform users.

3.13.7 Lighting

Lighting for roadways, driveways, and parking areas shall be provided as specified in Sections 3.13 and 7.7.

3.13.8 Preferred Parking for Hybrids/Carpools

The parking design should include preferred parking areas for low-emitting, fuel-efficient, and hybrid vehicles. Applicable vehicles generally include those that are classified as zero emissions vehicles (ZEV) by the California Air Resources Board or as having achieved a minimum green score of 40 on the American Council for an Energy Efficient Economy annual vehicle rating guide. Depending on the site location and the availability of low-emitting, fuel-efficient, hybrid or ZEV vehicles in the locale, facility managers and the appropriate EPA authority shall determine the level of stringency for the types of vehicles to include in preferred parking. Alternative fuel refueling stations should be considered on a facility-by-facility basis. Parking should also be designed to include preferred parking for carpools and vanpools.

3.13.9 Bicycle Parking

Convenient bicycle parking facilities shall be included at all facilities. Suitable means for securing the bikes must be provided, and sheltered/covered areas shall be provided at each EPA facility. Bicycle parking areas must be protected from motor vehicle traffic. Refer to Section 3.5.6 and 4.13.10 of this Manual for additional guidance.

3.13.10 Overflow/Special Events Parking

For facilities anticipated to require overflow and special events parking (i.e., for events such as conferences), it is recommended that such overflow parking areas be designed to minimize excess runoff, i.e., maximize use of grass surface and/or pervious pavers.

3.14 Exterior/Site Lighting

Exterior site lighting shall be designed to enhance safety and security on site, to provide adequate lighting for nighttime activities, and to highlight any special site features. While exterior site lighting should maintain safe light levels, site lighting should also be designed to minimize light trespass onto surrounding properties, particularly if there are adjoining residential areas, in order to minimize and mitigate night sky pollution. Lighting from the perimeter into the site is preferred. The maintained level of illumination shall be at least one to three foot-candles on roadways and walkways. The same type of lighting that is used for parking lots shall be used for roadways, and should be consistent with color and height. Energy efficient, low-voltage or solar powered lighting shall be used (i.e., Energy Star or FEMP-designated products, as required by Section 104 of EPAct 2005). The lighting level standards recommended by the IESNA Subcommittee on Off-Roadway Facilities are the lowest acceptable lighting levels for an EPA parking facility.

Refer to Section 7.7 for additional requirements for site lighting to prevent night sky effect and “light pollution.”

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4. ARCHITECTURAL AND BUILDING ENVELOPE REQUIREMENTS

4.1 General Goals and Requirements

4.1.1 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: (1) laboratory (where applicable), (2) administrative, and (3) building support. This division typically 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 promote 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. Where suitable for the design objectives, floor plates should be kept as narrow as possible to maximize daylighting opportunities.

The design of a Federal office building, particularly one located in the nation's capital, must meet a two-fold requirement. First, it must provide efficient and economical facilities for the use of Government agencies. Second, it must provide visual testimony to the dignity, enterprise, vigor, and stability of the American Government.

Accounting for functional needs is a primary purpose of the planning process that defines an owner's functional and physical requirements for each spatial element in a building or facility. Adequate planning will clearly delineate functional requirements and relations of occupant activities and spaces required for all supporting building systems and equipment. A truly functional building will require a thorough analysis of all aspects of the design, associated problem, and the application of creative synthesis in a solution that integrates the parts in a coherent and optimal operating manner.

The Public Buildings Amendments of 1988, 40 United States Code (U.S.C.) 3312 require that each building constructed or altered by any federal agency shall, to the maximum extent feasible, be in compliance with one of the nationally-recognized model building codes and with other applicable national recognized codes. Applicable codes and standards are listed in the appropriate sections of these Guidelines.

For office buildings, there are two ENERGY STAR requirements that are either in force or are pending:

- The January 2006 Federal Sustainable Buildings Memorandum of Understanding (MOU) requires that facilities slated to meet the five Guiding Principles in the MOU (15 percent of an agency's inventory by Fiscal Year [FY] 2016) must be benchmarked for energy consumption using the ENERGY STAR® Portfolio Manager tool for commercial buildings.

- Section 435 of the Energy Independence and Security Act of 2007 (EISA) requires that (with limited exceptions) within three years of enactment (December 19, 2010), all commercial-type office space leased by a Federal agency be in buildings that earned the ENERGY STAR label in the most recent year of operation. *As expressed in its Solicitation for Offers (SFO) for leased commercial-type space, EPA's current policy is that all new leases be ENERGY STAR-labeled, even before the EISA deadline takes effect. The ENERGY STAR label for commercial-type buildings does not apply to laboratory facilities.*

Consideration shall be given to materials and components that can be disassembled, disaggregated, and reused at the end of the building's useful life. Refer to EPA's *Deconstruction and Reuse* web page for additional information (http://www.epa.gov/osw/conserve/rrr/imr/cdm/reuse.htm).

4.1.2 Space Planning

The development of a well-organized design is the key first step in achieving a successful space plan. It assumes that the space planner is working from a program that lists the required number and approximate sizes of offices and workstations, as well as the support spaces associated with them. The program should also include special spaces specific to the project, such as laboratories, conference and training facilities, food service, child care centers, and fitness and health facilities. If the building to be occupied is known, the planner will develop the space layouts according to the building's characteristics.

4.1.3 Building Envelope Requirements

The building envelope includes everything that separates the interior of a building from the outdoor environment. The systems and elements that comprise the building envelope are each discrete assemblies that include: foundations, walls, roof, windows, doors, and floors. The prime functions of the building envelope are to provide shelter, security, solar and thermal control, moisture control, indoor air quality (IAQ) control, access to daylight, views to the outside, fire resistance, acoustics, and aesthetics. Each building envelope system has functional, performance, design, and construction elements that are specific to the needs of a facility and life-cycle cost effective. Because of the varied and sometimes competing functions associated with the building envelope, an integrated, synergistic approach considering all phases of the facility life cycle is warranted. This approach supports an increased commitment to environmental stewardship and conservation, and results in an optimal balance of cost, environmental, societal, and human benefits while meeting the mission and function of the intended facility.

In terms of functional requirements of the building envelope, each function (listed below) has its own performance standards and methods of measurement, methods of testing for compliance, and acceptability criteria. Building envelope functional requirements are as follows:

- **Structural:** If the wall is not part of the main building structure, support its own weight and transfer lateral loads to the building frame

- **Water:** Resist water penetration
- **Air:** Resist excessive air infiltration
- **Condensation:** Resist condensation on interior surfaces under normal service conditions
- **Movement:** Accommodate differential movement (caused by moisture, seasonal, or diurnal temperature variations, and structural movement)
- **Energy conservation:** Resist thermal transfer through radiation, convection, and conduction
- **Sound:** Attenuate sound transmission
- **Fire safety:** Provide "rated" resistance to heat and smoke. This is not required in all cases, NFPA, IBC, and state and local codes should be consulted for specific requirements that may apply.
- **Security:** Protect occupants from outside threats
- **Maintainability:** Allow access to components for maintenance, restoration, and replacement
- **Constructability:** Provide adequate clearances, alignments, and sequencing to allow integration of many components during construction, using available components and attainable workmanship
- **Durability:** Provide functional and aesthetic characteristics for a long time
- **Aesthetics:** Ensure that the exterior and interior appearance of the facility integrates well with its surroundings and is visually appealing
- **Economy:** Consider how to incorporate cost savings into facility development plans.
- **Building Layout:** Ensure that the building layout is functional and efficient and promotes interactions among staff, provides appropriate supporting facilities (rest rooms, break areas), and facilitates the movement and proper storage of supplies and wastes.

Thermal resistance parameters (e.g., "U" values) shall be prepared by following the recommended procedures documented in the ASHRAE *Handbook of Fundamentals* (latest edition) and shall exceed the minimum requirements specified in the International Energy Conservation Code (IECC).

4.1.4 Traffic Flow

Facilities shall comply with the following requirements and guidelines regarding traffic flow and site layout:

- 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

- 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.

4.2 Historic Preservation

Realizing the need to protect America's cultural resources, Congress established the National Historic Preservation Act (NHPA) in 1966. The NHPA mandates that Federal agencies use historic properties to the greatest extent possible, and strive to rehabilitate them in a manner that preserves their architectural character, in accordance with the Secretary of the Interior's *Standards for Rehabilitation*. Cultural resources, as identified in the National Register for Historic Places, include buildings, archeological sites, structures, objects, and historic districts. The surrounding landscape is often an integral part of a historic property. Not only can significant archaeological remains be destroyed during the course of construction, but the landscape (designed or natural) may be irreparably damaged; therefore, caution is advised whenever major physical intervention is required in an extant building or landscape. The Archaeological Resources Protection Act established the public mandate to protect these resources.

The following requirements apply for work on historic properties, or involving historic structures or historic landscapes:

- 36 CFR 68, *Standards for the Treatment of Historic Properties*
- 48 FR 22716, *Professional Qualifications Standards for Archaeology*
- Executive Order 11593, *Protection and Enhancement of the Cultural Environment*
- Executive Order 13006, *Locating Federal Agencies in Historic Buildings in Historic Districts in Our Central Cities*
- Executive Order 13287, *Preserve America*
- Section 106, 36 CFR Part 800, *Protection of Historic Properties*

- Cultural Resource Management Guideline, NPS-28
- Guidelines for Federal Agency Responsibilities, under §110 of NHPA
- The Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation* (as amended and annotated by the National Park Service)

- Archaeological Resources Protection Act

- Native American Graves Protection and Repatriation Act.

Work on historic properties requires specialized skills. The Secretary of the Interior has identified professional qualification standards for a variety of preservation disciplines, as described in 48 FR

22716, *The Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation*, September 29, 1983.

4.2.1 Alterations in Historic Structures

Where a historic structure is to be altered, special documents will be provided by EPA to help guide the design of the alterations. The most important of these is the Building Preservation Plan (BPP), which identifies zones of architectural importance, specific character-defining elements that should be preserved, and particular standards to be employed. Early and frequent coordination between the architect, State Historic Preservation Officer, Regional Historic Preservation Officer, preservation specialists, external review groups, and other appropriate EPA specialists is imperative to timely resolution of conflicts between renovation and preservation goals.

In general, alterations in historically significant spaces should be designed contextually to blend with the original materials, finishes, and detailing. When substantial repairs or alterations are undertaken in significant and highly visible locations, opportunities should be sought to restore original features that have been removed or insensitively altered.

Section 4.1.7(1) of the Americans with Disabilities Act (ADA) provides that, when an alteration is made to a qualified historic building, the alteration must fully comply with the requirements of the ADA Standards. Only in special circumstances may an alteration to a historic building be constructed without fully complying with ADA requirements for accessibility to, and use by, people with disabilities. Such special cirumstances may be found to exist only if, upon completion of the applicable process outlined in §4.1.7(2), the State Historic Preservation Officer finds that full compliance with ADA Standards would threaten or destroy the historic significance of the building. Upon receiving this finding in writing, the alternative requirements of §4.1.7(3) may be used, although EPA desires to, wherever possible, fully follow ADA guidelines.

4.3 Aesthetics and Functionality

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 the site and building into one concept

- The sequence of access, entry, and use of the building from the viewpoint of both staff and visitors 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. Interior paints and coatings shall be carefully selected so as to reflect light, increasing work surface illuminance while simultaneously minimizing glare and scattering.

4.3.1 Exterior Views

Visual contact with the outdoors provides occupants with cues about orientation, time of day, and weather, and are important for providing occupants a sense of well-being. The design of a building envelope provides the opportunity to incorporate views to the exterior surroundings from within most areas of the facility. Window design and placement can significantly affect not only the accessibility of vistas from a building, but is also critical in providing noise control and daylighting (which in urban environments are particularly difficult to optimize). 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.

EPA facilities can earn one point toward LEED-NC 2009 certification by providing a direct line of sight to the outdoor environment in 90 percent of all regularly occupied areas. Refer to the LEED Reference Guide for specific criteria.

4.3.2 Natural Lighting/Daylighting

Daylighting is the controlled admission of natural light into a space through windows to reduce or eliminate electric lighting. By providing a direct link to the dynamic and perpetually evolving patterns of outdoor illumination, daylighting helps create a visually stimulating and productive environment for building occupants, while reducing total building energy costs as much as one-third. Since lighting can account for a significant portion of a building's energy use, the incorporation of daylighting strategies to optimize natural lighting and increase the efficiency of supplemental lighting is a high priority for all new building and building renovation designs.

EPA seeks to minimize energy use dedicated to electric lighting and the resulting summertime cooling loads through proper use of natural lighting in its facilities. In effect, the Agency seeks a well-integrated lighting system for its new buildings (and major renovations) that makes optimum use of both natural and artificial lighting sources, while balancing the buildings' heating and cooling needs. A lighting power budget shall be determined, in conformance with the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)/Illuminating Engineers Society of North America (IESNA) 90.1-2004 (or latest version), 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 federal ENERGY STAR Program. In addition, when procuring energy consuming products, EPA shall procure either ENERGY STAR or Federal Energy Management (FEMP)-designated products, where available and life cycle cost-effective (§104 of the Energy Policy Act of 2005 [EPAct], Public Law 109-58) (refer to Section 6 of this Volume for additional details and to the following web site: http://www1.eere.energy.gov/femp/technologies/eep_purchasingspecs.html).

Reduction of lighting loads can also be accomplished through "climate-responsive design" or "passive solar design," including the orientation and size of windows, the location of landscape elements, and the use of high-performance building envelopes. Among the most important elements is simply the orientation of the building footprint on the site. Refer to Section 2.1, *Siting Requirements,* for further details on how the orientation of a building can be used to maximize the penetration of natural light into interior spaces and thus reduce utilization of artificial light.

4.3.3 Access Control for Buildings

Building perimeter barriers, intrusion detection devices, and protective lighting provide physical security safeguards; however, they alone are not enough. An access control system must be established and maintained to preclude unauthorized entry. Effective access control procedures prevent the introduction of harmful devices, materials and components. They also minimize the misappropriation, pilferage, or compromise of materiel or recorded information by controlling packages, materiels, and property movement. Access control rosters, personal recognition, ID cards, badge exchange procedures, and personnel escorts all contribute to an effective access control system. Access control will be managed and implemented at point of entry into the building. An adequate amount of space shall be allotted at the entrance (e.g. lobby, atrium) to accommodate access control equipment, security staff, visitors, and building occupants.

4.4 Construction Materials

EPA shall take an active role in the selection of the materials used on the project and during the construction process. The project architect, 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 encourages minimal use of products that are insensitive to the environment during and after manufacture and requires the project architect consider local manufacturers (less than 500 miles) if available, cost-effective, and able to provide the necessary volume of materials/products as required by the construction schedule. Construction materials shall have the highest practicable percentage of recovered materials, i.e., equal or greater than the minimums indicated in EPA's Comprehensive Procurement Guidelines (CPG). The specifications shall include environmental performance characteristics or other criteria to manage construction substitutions.

EPA facilities can earn points toward LEED NC 2009 certification under the Materials and Resources category by utilizing reused materials, recycled content materials, rapidly renewable materials, certified wood, and regional materials in the building process. Specific criteria for earning these points are provided in the LEED Reference Guide.

4.4.1 Wood and Agrifiber Products

Selection of wood products used as an interior finish should conform to requirements of "flame spread" and "smoke development" criteria by the International Building Code (IBC), and state and local codes. Any resins or varnishes used should be of low volatile organic compound (VOC)-emitting and low ozone-depleting materials. In general, low-VOC materials are those with maximum VOC content below the applicable target level contained in South Coast Air Quality Management District (SCAQMD) Rule 1113, *Architectural Coatings.* In general, low-ozone depleting materials are those with an ozone depletion potential (ODP) less than 0.02 (the ODP of HCFC-123 and HCFC-124), or lower value established by the EPA. The EPA project manager may specify more stringent definitions for a particular project.

Treated lumber should not be used for furnishings, especially for play equipment in daycare centers. Laboratory shelving and casework may be fabricated using wood (plywood) and plastic materials. Wood studs shall not be installed as part of new construction or as part of a major alteration or space adjustment.

EPA facilities can earn one LEED-NC 2009 point in the Indoor Environmental Quality category by using composite wood and agrifiber products that contain no added urea-formaldehyde resins.

The use of recycled materials should be maximized, as applicable, in accordance with the requirements of RCRA and designated products published in EPA's CPG (i.e., the Recovered Materials Advisory Notice (RMAN). 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 and agrifiber products are defined as; medium-density fiberboard (MDF) plywood, particleboard containing no urea-formaldehyde, wheatboard, strawboard, panel substrates, and door cores.

- Wood products certified by the Forest Stewardship Council (FSC) to be from managed sources (refer to Section 4.5.6 below).

With respect to wood products, the RMAN recommends that wood or wood composite materials contain 90 percent to 97 percent post-consumer recovered content.

4.4.2 Concrete

Concrete materials used for building construction shall comply with American Concrete Institute (ACI) 318, and state and local building codes, as applicable.

Consistent with §104 of EPAct 2005, specifications for construction projects involving concrete shall be written to consider the use of pozzolanic admixtures (i.e., silicacious fly ash, ground granulated blast furnace slag (GGBFS), high reactivity metakaolin (HRM), or silica fume), where feasible and as appropriate for the project. EPA encourages project designers and specifiers to consider one or more of these admixtures that best meets the project's performance requirements consistent with market availability and price considerations. EPA's CPG does not recommend specific recovered material content for concrete containing silicacious fly ash, BBBFS, HRM, or silica fume. However, the CPG contains several recommendations for maximizing the use of pozzolanic admixtures, as follows:

- Replacement rates of coal fly ash in the production of blended cement generally do not exceed 20 to 30 percent, although coal fly ash blended may range from 0 to 40 percent coal fly ash by weight, according to the ASTM C 595 standard, for admixture Types IP and I(PM). Fifteen (15) percent is a more accepted rate when coal fly ash is used as a partial cement replacement/admixture in concrete

- GGBFS may replace up to 70 percent of the Portland cement in some concrete mixtures. Most GGBFS concrete mixtures contain between 25 and 50 percent GGBFS by weight (ASTM C595)

- Concrete may contain a minimum of 10 percent cenospheres (by volume)

- Concrete containing silica fume may contain silica fume constituting 5 to 10 percent of cementitious material, on a dry weight basis.

The requirements of this section shall be used in conjunction with the structural design sections (i.e., Chapter 5 of this Manual). Concrete additives in floor slabs should be minimized, to avoid potential interaction with adhesives or sealants.

Refer to Chapter 5 of this Manual for additional information on concrete.

4.4.3 Metals

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) *Steel Construction Manual*, 13th Edition (AISC 325-05) (or latest edition)

- ASTM A992/A992M-06a, *Standard Specification for Structural Steel*

Steel joists and joist girders shall comply with the following:

- State building codes, as applicable

- Steel Joist Institute (SJI) National Standards (SJI_CJ COSP-1.0): Load Tables and Weight Tables for Steel Joists and Joist Girders.

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. 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. EPA's preference is to use steel from electric arc furnaces.

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

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 S201-07 Product Data Standard

Refer to Chapter 5 of this Manual for additional specifications for metals.

4.4.4 Glass

The choice of single-, double-, or triple-glazed windows should be based on climate and energy conservation and security requirements. Wherever possible, utilize the option with the highest level of recycled content. In most situations, double-glazed construction shall be the minimum performance standard to promote energy efficiency and compliance with ASHRAE 90.1-2004, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (or latest version). Whenever double- and triple-glazed units are specified, window frames shall have an appropriate thermal break. Highly-reflective glass that produces mirror images should be used with care to avoid creating glare in surrounding streets and buildings.

Windows should have a condensation resistance factor (CRF) adequate to prevent condensation from forming on the interior surfaces of the windows. The CRF may be determined by testing in accordance with American Architectural Manufacturers Association (AAMA) Guidance 1503-98. Where a CRF in excess of 60 is required, do not use windows unless some condensation can be tolerated or other methods are used to prevent or remove condensation.

4.4.5 Masonry

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.

Materials, design, and construction of masonry structures shall comply with the requirements of the applicable state and local building codes. Recycled, non-hazardous materials shall be used to the extent practical and allowed by the building codes. Local sources shall be used to the extent practical. Use ACI 530/530.1-08, *Building Code Requirements and Specifications for Masonry Structures*, as guidance for the design of masonry structures.

Requirements for materials, mixing, strength, and specifications for mortar and grout used in masonry structures shall comply with state and local building codes. Mortar and grout also shall be designed to comply with:

- ASTM C270, *Mortar for Unit Masonry*
- ASTM C476, *Grout for Masonry*.

Mortar shall be designed to give exposed masonry surfaces a desired architectural quality through color contrasts or shadow line from various joint-tooling procedures. Portland cement mortar should be used for all structural brickwork.

Refer to Chapter 5 of this Manual for additional information on masonry.

4.4.6 Plastics

Solid polymer material shall:

- Be a homogeneous, filled, solid polymer
- Not be coated, laminated, or of a composite construction
- Shall meet IAMPO Z124.3 and IAMP Z124.6 requirements.

Polymers shall have minimum physical and performance properties specified in Unified Facilities Criteria (UFC) 066116 (www.wbdg.org/ccb/). Superficial damage to a depth of 0.01 inch shall be repairable by sanding or polishing. Material thickness shall be as indicated on the drawings, but in no case shall the material be less than ¼ inch thickness. Exposed finished surfaces and edges shall receive a uniform appearance. Exposed surface finish shall be matte with gloss rating 5-50, depending on project requirements.

Permanently attached backsplashes shall be attached straight with seam adhesive to form a 90 degree transition, unless otherwise indicated. One-piece vanity top and bowl fabrications shall be a standard pre-fabricated product provided by the solid polymer manufacturer. Each unit shall include a vanity top with integral backsplash and sink bowl.

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. In cafeterias, cutouts for cold or hot appliances shall be made to templates furnished by the equipment manufacturers. Joints and cutouts shall be reinforced as recommended by the solid polymer manufacturer. Insulation shall be provided between the solid polymer surface and all appliances, hot and cold. Hot applications shall be thermally isolated from cold applications in accordance with the solid polymer manufacturer's recommendations. Provide expansion joints as necessary to accommodate hot appliances. Where cabinets exist beneath countertops, adequate ventilation shall be provided.

Floor-mounted, solid polymer toilet systems shall be provided to the dimensions shown on the project drawings. Panels and pilasters shall be fabricated from manufacturer's standard ½ inch thick sheet product, unless otherwise specified. Systems shall include all necessary hardware for installation and mounting of panels, pilasters, and doors.

Plastic materials should conform to requirements of the "flame spread" and "smoke developed" criteria in the International Building Code (IBC) when used as an interior finish, and should be of a low VOC-emitting or low ozone-depleting material. The CPG recommends the following minimum post-consumer content percentages:

- 25 to 100 percent for high-density polyethylene (HDPE) plastic lumber
- 50 percent for mixed plastics/cellulose
- 75 percent for HDPE/fiberglass
- 50 to 100 percent for other resins.

4.5 Sustainability Requirements for Materials

Section 2(d) of Executive Order (EO) 13423 specifies that the head of each agency (e.g., the Administrator of EPA) shall "require in agency acquisitions of goods and services: (i) use of sustainable environmental practices, including acquisition of biobased, environmentally preferable, energy-efficient, water-efficient, and recycled-content products; and (ii) use of paper of at least 30 percent post-consumer fiber content. In addition, section 2(h) of Executive Order 13514 requires that material acquisition ensure "that 95 percent of new contract actions including task and delivery orders, for products and services….are energy-efficient (Energy Star or Federal Energy Management Program (FEMP) designated), water-efficient, biobased, environmentally preferable (e.g., Electronic Product Environmental Assessment Tool (EPEAT) certified), non-ozone depleting, contain recycled content, or are non-toxic or lesstoxic alternatives." Specifications for several of these materials are provided in the following sub-sections.

4.5.1 Recycled Content

EPA is required to buy recycled-content products as designated in the Comprehensive Procurement Guidelines (CPG). Architects and engineers should always make environmentally responsible choices regarding new building materials and the disposal of discarded products. Buying recycled-content products aids in: (1) developing markets for materials collected in post-consumer residential and commercial recycling programs; and (2) encouraging manufacturers to include the maximum pre-consumer wastes (e.g., excess inventory, returned items) in their products.

EPA facilities that use materials with recycled content such that the sum of post-consumer recycled content plus one-half of the pre-consumer content constitutes at least 10 or 20 percent, based on cost, of the total value of the materials in the project, can earn LEED NC 2009 points under the Materials and Resources category. Refer to the LEED Reference Guide for specific requirements..

EPA also issues guidance on buying recycled-content products in RMANs. The RMANs recommend recycled-content ranges for CPG products based on current information on commercially available recycled-content products. RMAN levels are updated by EPA as marketplace conditions change.

Architects and engineers must maximize the opportunity for contractors to bid recycled-content materials by including CPG items in the design specifications. Exceptions to recycled-content materials requirements will only be permitted if written justification is provided when a product is not available competitively, not available within a reasonable time frame, does not meet appropriate performance standards, or is only available at an unreasonable price.

4.5.2 EPA Comprehensive Procurement Guidelines (CPGs)

EPA's CPG program is authorized by Congress under §6002 of RCRA. Under the provisions of §6002, the EPA is required to designate products that are (or can be) made with recovered materials, and to recommend practices for buying these products. Once a product is designated, procuring agencies (including construction contractors) are required to purchase the product with the highest recovered material content level practicable and cost-effective.

EPA is required to review existing product designations in the CPG for effectiveness, obsolescence, and consistency with the product designations under the biobased products designation program, environmentally preferable purchasing program, and ENERGY STAR and FEMP-designated energy efficient products program. EPA will delete those designations that are ineffective in meeting the objectives of RCRA §6002 or are obsolete due to market changes. Check the latest version of the CPGs before making procurement decisions (http://www.epa.gov/waste/conserve/tools/cpg/index.htm) EPA shall use sustainable environmental practices, including acquisition of recycled content products, where such products meet agency's performance requirements (E.O. 13514).

4.5.3 Biobased Materials

The Farm Security and Rural Investment Act (FSRIA) of 2002 includes a mandate to the U.S. Department of Agriculture (USDA) to develop and implement a comprehensive program for designating biobased products and a directive to all federal agencies to increase their purchase and use of "preferred" products. The resulting USDA BioPreferred program lists designated products that must contain biobased material with recommendations for the percentages of biobased content (http://www.biopreferred.gov). The rules for use of designated products are the same as EPA CPG. EPA shall use sustainable environmental practices, including acquisition of biobased products, where such products meet the Agency's performance requirements (EOs 13423 and 13514).

BioPreferred construction and building materials include asphalt and tar removers; asphalt restorers; biodegradable foams; cellulose and batt insulation; composite panels; concrete and asphalt release fluids; concrete curing agents; concrete repair patch; floor coverings; lumber, millwork, and underlayment, masonry and paving, mulch and compost, paints and coatings, spray insulating foams, roof coatings , wood and concrete sealers, and wood anc concrete stains.

4.5.4 Renewable Resources

Most building materials necessitate the consumption of large amounts of natural resources. Rapidly renewable materials are materials that regenerate themselves faster than traditional extraction demand (i.e., planted and harvested in less than a 10-year cycle) and do not result in significant biodiversity loss, increased erosion, or air quality impacts. Rapidly renewable materials should be incorporated into

EPA facilities can earn one LEED NC point in the Materials and Resources category if rapidly renewable building materials and products for 2.5 percent (or greater) of the total value of all building materials and products are used in the project, based on cost.

both permanent building elements and interior accessories, where technically feasible and cost-effective. Many materials that meet the definition of biobased are also rapidly renewable materials, Typical examples of rapidly renewable materials include bamboo, wool, cotton, agrifiber, linoleum, wheatboard, strawboard, and cork. Designers should establish objectives for the use of rapidly renewable materials and identify where such materials can be applied as substitutes for more commonly used resource-intensive materials.

4.5.5 Locally-Sourced Materials

EPA shall attempt to purchase locally-sourced materials. The utilization of locally-sourced materials can increase the demand for building materials and products that are extracted and manufactured within the region, and thus support regional economic growth and reduce the environmental impacts associated with the transportation of building materials. The transportation of materials contributes to the carbon footprint of a facility. The energy efficiency of a building once it is completed has become a primary focus for many developers, yet the embodied energy associated with the manufacturing, transportation, and installation of building materials is also an important factor in building design.

If building materials or products are used that have been extracted, harvested or recovered, as well as manufactured, within 500 miles of the project site for a minimum of 10 percent (based on cost) of the total materials value, EPA facilities can earn LEED-NC points in the Materials and Resources category. Refer to the LEED Reference Guide for specific criteria.

4.5.6 Certified Wood from Sustainably Managed Forests

EPA shall use certified wood to assure that forestry practices are environmentally responsible, socially beneficial, and economically viable. This may include wood and wood products certified by the Forest Stewardship Council (FSC) or comparable, recognized third-party organization..

If a minimum of 50 percent (based on cost) of wood-based materials and products incorporated into the project are certified in accordance with FSC guidelines, EPA facilities can earn one LEED-NC point under the Materials and Resources category. (*Note that LEED specifically requires FSC certification and does not recognize certifications by other, similar organizations)*.

4.6 Walls

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.

4.6.1 Load-Bearing Walls

Design load-bearing walls in accordance with applicable codes and standards to safely support project dead loads, live loads, seismic load, and lateral wind loads without excessive stress or deflection. Relevant standards and specifications steel framing include:

- AISI, *Specification for the Design of Cold-Formed Steel Structural Members*
- ASTM C1007, *Standard Specification for Installation of Load-bearing (Transverse and Axial) Steel Studs and Related Accessories*

- ASTM C955, *Standard Specification for Load-Bearing (Transverse and Axial) Steel Studs, Runners (Tracks), and Bracing or Bridging for Screw Application of Gypsum Panel Products and Metal Plaster Bases.*

Refer to Chapter 5 of this Manual for additional information.

4.6.2 Curtain Walls

A curtain wall is a non-load bearing wall, usually aluminum-framed, and containing in-fills of glass, metal panels, or thin stone. The framing is attached to the building structure and does not carry the floor or roof loads of the building. The wind and gravity loads of the curtain wall are transferred to the building structure, typically at the floor line.

All panel and curtain walls shall conform to the requirements for non-load bearing walls for the type of construction and model code involved, and shall be securely anchored to the building in a manner that will prevent: (1) failure of the anchors in a fire, or (2) failure of the panel and its components under high wind load conditions.

4.6.3 Interior Partitions

Partitions should be selected for use based on the type of space and the anticipated activity within that space. The following should be evaluated:

- The number of people
- Code requirements
- Sound isolation requirements
- Security
- Protection from moving equipment
- Equipment that will impose lateral loads
- Any free-standing, moveable, or wall-mounted equipment that will impose lateral loads (built-in cabinets or bookshelves, wall-mounted televisions, etc.).

4.6.4 Insulation

Insulation ranks as one of the best means of saving energy in buildings and reducing utility bills. Insulation provides resistance to the flow of heat from a building's exterior to its interior, and vice versa. Insulation is primarily either loose-fill, batt, rigid boardstock, or foamed-in-place.

Selection issues for insulation include:

- R-value performance (including changes over time)
- Environmental impacts during manufacture, including whether hydrochlorofluorocarbons were used
- Recycled content

- Durability
- Waste generated
- Potential health hazards.

Facility planners should specify R-values (thermal resistance) that minimize life-cycle costs for all new construction. The insulation selected should conform to the relevant fire resistance rating, pest-resistance, and product standards of ASTM and others. ASHRAE 90.1 specifies insulation requirements for various building envelope components, depending on heating degree-days and other factors.

Minimum recycled content of different types of insulation is specified in the recycled-content product guidelines developed by EPA in accordance with §6002 of RCRA. The RMAN for building insulation products specifies minimum recycled content for rock wool; fiberglass; cellulose (loose-fill and spray-on); perlite composite board; plastic rigid foam (polyisocyanurate/polyurethane); and plastic, non-woven batt.

4.6.5 Concrete Masonry Units

Concrete masonry units (CMUs) are fabricated from a mixture of Portland cement and aggregates under controlled conditions. The units can supplied in various dimensions, but typically have face dimensions of eight inches high by 16 inches wide (nominal). CMUs are typically formed to the desired shape and then pressure-cured at the manufacturing plant. CMUs are often used when masonry is to form a load-bearing wall or an interior partition between spaces within a building. CMUs can be manufactured in different sizes and with a variety of face textures.

CMUs should meet the requirements of ASTM C90, *Standard Specification for Load-Bearing Concrete Masonry Units.* The units are categorized based on their weight (lightweight, normal weight and heavyweight). CMUs for structural applications are either normal weight or heavyweight. Lightweight units are used for non-load bearing conditions or as veneers.

4.7 Ceilings

4.7.1 General Purpose Ceiling

Ceilings tiles or panels shall contain recycled content, acoustical ceiling tiles shall have a recycled content conforming to EPA's CPG requirement of 80 percent.

Ceilings shall generally have a minimum noise reduction coefficient (NRC) of 0.60 (preferably 0.80 is open office areas and between 0.75 and 0.85 in conference rooms. The NRC shall be deteremined in accordance with the methods specified in ASTM C423-09a, *Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.* Open ceilings are acceptable, provided that noise reduction is considered and EPA's minimum requirements for noise control (as specified by the Project Manager) are achieved..

4.7.2 Special Purpose Ceilings

Ceilings with a washable surface, such as washable lay-in acoustical tiles (Mylar® face with smooth surface or equivalent) shall be provided for most spaces. Ceiling heights shall be at least 9.5 feet in laboratory spaces and support spaces, and shall be a minimum of 8.5 feet in administrative spaces. Gypsum board with epoxy paint ceilings, equipped with access panels, shall be provided in glassware washing and autoclave rooms, and other locations where a high moisture level exists. Access panels shall be fitted with gaskets that seal the door when closed and also seal the flange around the panel lip where it meets the ceiling. Open ceilings are acceptable, provided that:

- Minimal ducting and piping are present

- All exposed surfaces are smooth and cleanable.

Ceilings tiles or panels shall contain recycled content, acoustical ceiling tiles shall have a recycled content conforming to EPA's CPG requirement of 80 percent.

4.8 Windows

Window systems are comprised of glass panes, structural frames, spacers, and sealants. In recent years, the variety of glass types, coatings, and frames available for use in window systems has increased dramatically, as has the opportunity to fine-tune and optimize window selection on a project-by-project basis. Careful specification of window and glazing systems is essential to the energy efficiency and comfort of all EPA buildings.

Windows systems shall be energy-efficient, as specified herein, to the degree it is life cycle cost-effective. The baseline standard for EPA buildings shall be double-glazed windows, except where unnecessary due to climate or otherwise impracticable. All window treatment selections shall be coordinated with other interior finishes by the Project Architect or Interior Designer. Light-tight treatments shall be provided in conference rooms, laboratories, and other spaces that may need to be darkened. The type of window treatment utilized shall aid in maintaining a consistent visual appearance on the exterior of the building.

To fully specify a window system, it is necessary to specify the following characteristics:

- Window U-value
- Window Solar Heat Gain Coefficient (SHGC) or shading coefficient (SC)
- Glass Visible Transmittance ($T_{vis\text{-}glass}$)

For specific aesthetic and performance objectives the specifier may also wish to specify:

- Tints (colors) and Coatings

Some recommendations for specifying windows and glazings include:

- When specifying windows performance, take care to specify "whole product performance values" for U-factor and SHGC. Use of "glass-only" U-factors should be avoided, because they can overestimate the whole product value by up to 40 percent. In climates with significant air conditioning loads, specify windows with low SHGC values (< 0.40)
- In general, high (> 70%) Glass Visible Transmittance is desired, especially for daylighting applications
- For commercial buildings, in conjunction with daylighting strategies, analyze the trade-offs between standard glazing and high coolness index (also called spectrally-selective) glass. Spectrally-selective glass has a relatively high visible transmittance and a relatively low SHGC
- In general, low SHGC windows should be considered for east- and west-facing glazing as a means of controlling solar heat gain and increasing occupant comfort. For large commercial and industrial structures, specify low SHGC windows on the east, south, and west facades. SHGC for north-facing windows is not critical for most latitudes in the continental United States

- For buildings where passive solar heating energy is desired, south-facing windows with high SHGC values coupled with low U-factors should be specified
- Select windows with comfort in mind. The proper specification of windows can result in higher Mean Radiant Temperature (MRT) in winter and lower MRT in summer, thus improving occupant comfort and productivity. (*MRT represents the average temperature an occupant experiences from radiant heat exchange with their surroundings*).

Window size, head-height, placement, number, and location shall be determined on the basis of need for natural light and ventilation, also taking into account energy efficiency. All exterior windows in heated or air-conditioned spaces shall use double-glazed, insulated, low-emissivity (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. When procuring energy consuming products, EPA is required to procure either ENERGY STAR® or FEMP-designated products (EPAct, §104). Currently, ENERGY STAR® and FEMP both have issued specifications for residential (but not commercial) windows. Project Architects and Engineers shall monitor the possible development of commercial window specifications and use, as applicable, once they are adopted.

An important design consideration for operable windows is resistance to wind loads in the open position. Unfortunately, the industry provides little guidance on this issue. Sliding seal windows are always supported on two sides, whether open or closed. Projecting windows rely on operating hardware for support against wind loads. The operating hardware for projecting windows may not be adequate for severe exposures.

Commonly-used window frame materials include aluminum, steel, and wood. Aluminum frames are the most widely used window frame material, and provide design flexibility because of the wide range of available stock systems and the relative economy of creating custom extrusions. Design flexibility is generally limited by the available stock rolled shapes. The cost premium for custom shapes is larger for steel frames than for aluminum frames.

A critical element of successful window design is integration with adjacent wall components to create a functioning wall system. Reliable wall system design generally includes a water-resistant barrier behind the wall cladding, an air barrier, and sometimes a vapor retarder. The "punched" window openings in the wall system threaten to create holes in the water/air/vapor barrier(s). Careful detailing is required to integrate water/air/vapor barriers with the window frames and maintain their continuity at the window perimeters.

Wherever windows extend to within 36 inches of the finished floor and are at least four feet above the existing 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 1201, and the local building code, no barriers are required. Additional window security requirements are contained in Section 4.14.

4.9 Doors

4.9.1 Exterior Doors

Exterior doors shall: (1) be weather-tight, (2) equipped with door closers, (3) open outward, and (4) have a drip rain diverter above the door, as required. Doors shall comply with requirements of the Uniform Federal Accessibility Standards (UFAS), ABAAS, and NFPA 101, as applicable. Exterior doors shall be alarmed for anti-intrusion.

4.9.2 Interior Doors

Interior doors must have a minimum opening of 32 inches (width) by 80 inches (height) and shall comply with ABAAS and/or UFAS, as applicable. Hollow-core wood doors are not acceptable. All hardware shall be ABAAS-compliant. Doors shall be operable by a single effort and shall be provided with vision panels in accordance with all applicable code requirements. In new laboratories and where required by NFPA 101, NFPA 45, or other codes or standards, exit and exit-access doors shall swing in the direction of egress.

4.9.3 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: (1) at least five feet from the swing side of the door, (2) four feet from the opposite side, and (3) at least 1½ feet past the latch side (pull side) of the door and one foot past the latch side (push side).

4.9.4 Fire Doors

Fire doors shall conform to NFPA 80 and the IBC. Doors, hardware, and frames shall bear the label of Underwriters Laboratories (UL), Factory Mutual (FM), or another approved laboratory testing organization..

Glazing material shall not be allowed in fire doors with a three-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 one- 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 one-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 by applicable codes and standards.

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 Chapter 6 of this Manual. For additional fire protection requirements, refer to Chapter 9 of this Manual.

4.9.5 Laboratory Doors

Laboratory doors shall be 48 inches wide (32 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 six inches into exit access corridors. In general, large vision panels should be provided to allow easy and quick safety inspection of laboratory spaces. Hardware shall be ABAAS-compliant and shall provide various levels of access control, as required—both combination and key access locks. Areas where a high level of security will be required shall be provided with card-key access control.

Laboratory doors are considered high-use doors. All hardware shall be specified to withstand this type of use. Light, commercial grade hardware shall not be specified. All hardware must meet security, accessibility, and life safety requirements. Doors should be fitted with kick plates.

4.9.6 Entry Doors

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. The main entrance must be easily recognizable and allow easy transition to other facility areas by first-time users of the facility. All major entryways should have vestibules and walk-off grilles to capture dirt, unless these are prohibited by historic preservation requirements.

Unless otherwise specified, 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 NFPA 80, as applicable.

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 two-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 on-site EPA Facility Manager must be furnished with at least two master keys and two keys for each lock. Hardware for egress doors shall conform to NFPA 101 and ADA requirements.

4.9.7 Personnel Doors

In order to protect those who work in and visit EPA facilities, personnel doors equipped with security technologies shall be installed in EPA facilities. The first line of security within a federal building is to channel all access through entry control points. Personnel doors ensure that only designated individuals have access to specific areas of a federal facility. Personnel doors can be outfitted with identity verification devices, such as automatic readers of special identification cards or keypad entry devices. Technologies used by identity verification devices include the basic bar code or magnetic strip for card-swipe readers.

It is important not to locate personnel doors between wheels and edge of hangar door leaf. The exact location of personnel doors should be determined by structural design of the door leaf. The door manufacturer shall provide the structural frames for supporting the door. Each personnel door shall be provided with an electrical interlock switch to prevent motor operation of the leaf (or group in which it is located) when the personnel door is open. Provide an identified indicator light at each door leaf control station, which indicates when the personnel door is in the open position.

4.9.8 Roll-up and Vehicle Access Doors

Electric roll-up doors shall contain a safety device on the bottom edge of the door. The device shall immediately stop and reverse the door movement during the closing travel, upon contact with an obstruction in the door opening or upon failure of any component of the control system. In addition, the door's closing circuit shall automatically lock out (but allow the door to be manually operated) until the failure or damage has been corrected.

Roll-up doors shall conform to the specifications in ANSI/SDI A250.8-2003 (or latest version), published by the Steel Door Institute (SDI) and otherwise known as SDI-100, *Recommended Specifications for Standard Steel Doors and Frames.* SDI-100 defines four levels of door construction requirements, depending on the expected type of service: Standard Duty (Level 1), Heavy Duty (Level 2), Extra Heavy Duty (Level 3), and Maximum Duty (Level 4). These levels dictate minimum thicknesses of doors and frames for each application. Other SDI-100 specifications, such as those pertaining to materials of construction, door hardware, etc., shall also be followed.

Exterior doors shall be provided with weatherproof joints between sections, e.g., a rubber or vinyl adjustable weatherstrip at the top and a compressible neoprene or rubber weather seal attached to the bottom of the door. On exterior doors that are electrically-operated, the bottom seal shall be a combination compressible weather seal and safety device for stopping and reversing door movement.

4.9.9 Egress Doors

Fire doors in exits or means of egress shall also conform to the requirements contained in Chapter 9 of this Manual.

4.10 Architectural Finishes

Design features and materials selected for the construction of EPA offices, laboratories, and other facilities shall:

- Be durable, smooth, and cleanable
- Provide ease of maintenance
- Minimize pest access
- Contribute to creation and maintenance of a comfortable, productive, and safe indoor environment.

EPA facilities can earn LEED NC 2009points under the Indoor Environmental Quality category by using low-VOC emitting adhesives and sealants, paints and coatings ,and flooring systems. Specific criteria for earning these points are provided in the LEED Reference Guide.

Materials for laboratory finishes shall be as resistant as possible to the corrosive chemical activity of disinfectants, cleanup solvents, and other chemicals used (provided that life cycle costs are not deemed excessive by EPA). Selection of materials and design of penetrations through walls and floors usually have an impact on fire safety—for additional fire safety requirements, refer to Chapter 9 of this Manual.

The required finishes for each room are specified in the room data sheets or finish schedules in the Project Construction Specifications or EPA's Program of Requirements (PORs). 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.

Additional information regarding finishes is provided in the following sections:

- Flooring – Section 4.11
- Walls– Section 4.6
- Ceilings – Section 4.7

- Windows and window treatments – Section 4.8
- Doors and door hardware – Section 4.9.

The required finishes must be designated for each room in the Room Data Sheets. The project architect shall make material selections in consultation with the users. They are also responsible to select finish materials for items in areas that are not specifically designated in the Room Data Sheets. Material Safety Data Sheets (MSDS') will be used as a resource for environment evaluation for finish selections. The selection of interior finishes shall consider the following environmental measures:

- <u>Indoor Air Quality</u>
  - Low or no VOC paints, adhesives, and caulks
  - Low or no VOC non-chlorine based wall base, wall covering, and flooring
- <u>Maximize Recycled Content (refer to specific, applicable CPGs)</u>
  - Carpet
  - Wallboard
  - Base
  - Cove molding
  - Concrete
  - Steel
  - Ceiling tiles

4.10.1 Wall Surfaces

Wall surfaces shall be free from cracks, unsealed penetrations, and imperfect junctions with ceiling and floors. Materials shall be capable of withstanding washing with strong detergents and disinfectants, and be capable of withstanding the impact of normal traffic inside and outside the building envelope, as applicable. Corner guides and bumper rails shall be provided to protect wall surfaces in high traffic/impact areas.

4.10.2 Wall Coverings

Wall coverings made of materials that are considered "environmentally friendly" shall be provided in the administrative and other office areas when required (laboratory areas shall not have wall coverings). Such wall coverings shall meet the following criteria:

- **Construction**: All material shall be of uniform color throughout. Non-chlorine based materials are preferable. Recycled content laminated paperboard and/or structural fiberboard should be specified consistent with applicable CPGs
- **Maintenance properties**: All wall coverings shall be resistant to permanent stains and mildew and shall be capable of being cleaned with mild, non-abrasive cleaners. 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

- **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 E84-09, *Standard Test Method for Surface Burning Characteristics of Building Materials* (or latest version)

- **Application:** Application of all wall coverings shall be performed in accordance with the manufacturer's recommendations. In the product selection process, consider and minimize (where possible) the impact from releases of VOCs to indoor air associated with the manufacturer's recommended application method.

4.10.3 Paint

Paint shall be carefully selected to prepare a smooth and durable finish using the minimum amount of any materials such as thinners that could precipitate IAQ issues for the occupants. Paints, coatings, primers, undercoats (including clear wood finishes, stains, sealers, and shellacs) shall meet the maximum VOC content requirements in the latest edition of the following standards, as applicable:

- For architectural paints, coatings, and primers applied to interior walls and ceilings, the latest edition of Green Seal Standard GS-11, *Paints and Coatings*

- For all other architectural coatings, primers, and undercoats (including clear wood finishes, floor coatings, stains, sealers, and shellacs), the latest version of South Coast Air Quality Management District (SCAQMD) Rule 1113, *Architectural Coatings.*

Use reprocessed latex paint in accordance with EPA's CPG (Comprehensive Procurement Guidelines) on all painted surfaces where feasible. Follow the manufacturer's recommendations for the application and maintenance of all paint products. All paint shall be brush-applied only; spray painting is not allowed on site.

4.10.3.1 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.

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.

4.10.3.2 Wall And Ceiling Colors

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

4.10.3.3 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.

4.10.3.4 Lead-Based Paint Prohibition

Lead-based paint shall not be used in EPA facilities.

4.10.4 Carpeting

Carpets should be used in all areas where acoustics are a concern, most notably in office working areas. Carpet tiles should be used whenever there is access flooring, a cellular floor, or a ducted floor system, so that maintenance of systems under the floor can be done without destroying the carpet. Carpet tiles shall cover all typical office floors and must meet static buildup and flammability requirements, as described below. 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 four-Phenylcyclohexene (4PC) rubber should be avoided Secondary backing material shall have a minimum 30 percent recycled content

- Total weight: Minimum of 130 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 exitways must have a CRF of at least 0.50. Carpet passing the Consumer Products Safety Commission FF1-70 (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

- End of life/disposal: Required to be recyclable by manufacturer.

EPA facilities can earn LEED-NC 2009 points under the Indoor Environmental Quality category for carpeting systems that meet the following conditions: (1) All carpet installed in the building interior meets the testing and product requirements of the CRI's Green Label Plus Program, (2) All carpet cushion installed in the building interior meets the requirements of the CRI's Green Label program, and (3) All carpet adhesive has a VOC content of 50 grams per liter (g/L) or lower.

Off-gassing of harmful chemicals from carpet installations into the interior is a serious health concern. To minimize off-gassing that adversely affects indoor air quality, all carpet materials, including carpet fibers, backing, cushion, and adhesives, shall meet or exceed the Carpet and Rug Institute's (CRI's) "Green Label" criteria and contain recycled, renewable, and/or reusable materials to the greatest extent practicable. Preferred materials for carpet backing and cushioning are those containing natural fibers, polyolefin, polyvinyl butyral, polypropylene, polyurethane, or urethane.

When specifying a carpet that complies with the above environmental criteria, care must be taken to verify it also meets all the criteria for its intended use and level of foot traffic. The amount of foot traffic and soiling should be considered when selecting carpet. The CRI has developed test criteria for rating carpet in each of three classifications: severe traffic, heavy traffic, and moderate traffic. A selection of carpet for a lower foot traffic level than anticipated is discouraged.

4.10.4.1 Color

For new carpet, the EPA Project Manager 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 during manufacture.

4.10.4.2 Installation

Carpet must be installed in accordance with the approved manufacturer's instructions and the following specifications:

- 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 rubber base.

- 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.

4.11 Flooring

The base floor within a building may simply be a cast-in-place concrete slab-on-grade with limited design considerations for structural support or environmental control functions. The base floor may also be comprised of a mud or structural foundation slab complete with waterproofing and wearing slab, with the overall system designed to carry structural hydrostatic pressure loads and maintain a controlled environment. Floor slabs are often the source of leakage into the building, with slab cracking of common concrete materials being a primary cause. In certain areas of the U.S., preventing or controlling intrusion of soil gas emissions (e.g., naturally-occurring radon[4], residual VOC contamination in soils at brownfield sites) may also be of importance.

[4] The portions of the United States most impacted by naturally-occurring radon in soil (greater than four picocuries per liter) in New England, the middle Atlantic states, Appalachia, Great Lakes and Upper Midwest, and the northern Rocky Mountain states. Isolated pockets of these areas exist in other states, such as New Mexico and Nevada.

4.11.1 Flooring—General

All adjoining floor areas shall be of a common level, not varying more than 0.25 inches over a 10-foot horizontal run (in accordance with American Concrete Institute standards) and non-slip construction. For spaces where raised floors will be installed (e.g., for data cabling and/or underfloor air distribution systems), the use of depressed slabs is preferred to avoid level changes and the necessity for ramps. Floors shall have minimum live load capacities as follows:

- **Office areas:** 50 pounds per ANSI/BOMA Office Area square foot (lb/ft^2) (preferably 80 lb/ft^2) plus 20 lb/ft^2 for moveable partitions. At least 10 percent of each floor of office area shall have a minimum live load capacity of 100 lb/ft^2 (preferably 150 lb/ft^2) for high-density filing and library stacks.

- **Basements or lower levels:** A percentage of the square footage in basements or lower levels shall have a minimum live load capacity of 200 lb/ft^2 and include moveable partitions for storage requirements. This percentage will be specified by the Project Manager for each project.

Plans and specifications showing the floor load capacity, signed and stamped by a registered professional engineer (civil or structural specialization), shall be submitted to the Project Manager. Backup calculations and drawings may also be required to be submitted, on a case-by-case basis.

Floor treatments shall be compatible with the intended use of the room and shall emphasize durability,low maintenance, and the use of sustainable materials. Materials may be wood, carpet, linoleum, concrete, or terrazzo. Exposed interior floors in primary entrances and lobbies shall be marble, granite, or terrazzo. Exposed interior floors in secondary entrances, elevator lobbies, and primary interior corridors shall be high-grade carpet, marble, granite, terrazzo, or durable composite tile. Resilient flooring shall be used in telecommunications rooms. Floor perimeters at partitions shall have wood, rubber, marble, or carpet base.

In all toilet and service areas, terrazzo, unglazed ceramic tile, recycled glass tile, and/or quarry tile shall be used. All ceramic tile shall have a minimum recycled content of 50 percent.

When floor tiles or carpet are used, preference should be given to such items designated in the applicable CPG. Materials must be smooth, non-absorbent, skid-proof, and wear-resistant. Depending on the interior space, the finished floor covering may be the exposed concrete surface itself or various floor coverings such as wood, or carpet. Many adhesives used in applying floor coverings are sensitive to moisture, therefore requiring the use of a waterproof system or lengthy drying times if a polymer-based (poly) vapor retarder is used.

Floor materials shall be installed to allow for cleaning with liquid disinfectants and/or mild solvents, and to minimize the potential spread of spills. The base may be a four-inch high, readily cleanable <u>recycled</u> rubber material. Where a monolithic floor is used, install either a four-inch high integrally coved sheet flooring or a readily cleanable four-inch high recycled rubber base.

4.11.2 Flooring—Laboratory Spaces

Laboratory flooring shall consist of a monolithic concrete floor slab, with a chemically-resistant, skid-proof coating applied, where necessary. Flooring that is not slab-on-grade construction shall be supported by a one-way concrete joist system. The floor shall be capable of supporting a minimum total load (static plus live loads) of 150 lb/ft^2 in both laboratory modules and in storage and receiving areas.

Laboratory flooring should be resistant to the adverse effects of acids, solvents, and detergents. When a seamless floor material is required, the base shall also be seamless and integrally coved.

4.11.3 Flooring—Exposed Concrete

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: (1) penetrating-type solvent base; or (2) water-emulsion base sealer containing a suitable type resin and no wax or pigments. Sealers on parking garage ramps and decks that be a high penetration silane sealer providing a minimum 95 percent screening per National Cooperative Highway Research Program (NCHRP) No. 244 standards for chloride ion penetration resistance.

4.11.4 Wood Floors

Wood floors provide the environmental benefits of a renewable and long-lasting material, and they can be disassembled and reused or recycled at the end of their useful life. Wood flooring requires periodic refinishing, however, which can be a source of VOC and wood dust emissions. Laminates minimize the use of nonrenewable resources by bonding a thin, resilient surface onto a strong, high-density fiberboard made of recycled wood.

4.11.5 Tile & Stone

Concrete masonry design shall follow the recommendations of the National Concrete Masonry Association (NCMA) contained in the publication, *TEK Notes.* 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: (1) penetrating-type solvent base; or (2) water-emulsion base sealer containing a suitable type resin and no wax or pigments.

Masonry must be installed on a solid, rigid base. This is typically a concrete foundation or structural steel or concrete beam system. Most building codes do not allow the weight of the masonry to be supported by wood framing, due to the strength loss of the wood member when exposed to moisture. The support system must be designed for small deflections (typically 1/600th of the span) to avoid cracking of the masonry.

The masonry units are laid in a bed of mortar. The horizontal joints between units are called bed joints, while the vertical joints are called head joints. Clay brick masonry should include solid (full) head and bed joints. In concrete masonry it is common to lay the units with mortar only on the face shells (face shell bedding). This is due to the size of the cores and the difficulty in installing the correct amount of mortar in the webs between cores. Full bedding of concrete masonry units is typically only performed where a portion of the cells will be filled with grout. Where grouting is performed, mortar should be kept from falling into the cells, since this will form a weak plane in the grout.

Mortar is typically composed of cement, lime, and sand. Components and proportions of mortars vary depending on the desired mortar properties. Mortars consisting of Portland cement and lime as well as sand are most common. Premixed mortars must be carefully reviewed to determine the actual components of the mix.

There are different mortar types depending on the required strength. Mortars for new construction are typically Types N, S, or M. For repairs to existing buildings, some other types such as Type O, or even softer mortars, may be required to replicate the original mortar properties. The most common masonry types and uses in new construction are as follows:

- Type N—Used in general masonry walls above grade. This is the most common masonry mortar used in non-structural applications in new construction. This has good bond qualities and good resistance to water penetration

- Type S—Typically used in structural masonry applications. Has a higher proportion of cement and subsequently can have increased shrinkage of the mortar

- Type M—Typically used only in below-grade applications.

Mortar proportions and mixing requirements are outlined in ASTM C270 and in the appropriate Technical Notes published by the Brick Industry Association (BIA). Generally, mortars are mixed on site with water to achieve a wet fluid mix, with sufficient water for workability. The mortar is re-tempered (additional water added to the mix) periodically to maintain workability. After two hours, the bond of fresh unused mortar to new units is significantly reduced. Therefore, mortar that is unused within two hours should be discarded.

4.11.6 Vapor Barriers

Guidelines for vapor barriers are provided in Chapter 3 of this Manual.

4.12 Roofing

Low-sloped roofs are defined as those roofs with a slope less than or equal to 3:12 (25 percent). However, with the exception of metal roofs, most low-slope roofs have a slope of about ¼:12 (two percent). Steep-slope roofs are defined as those roofs with a slope greater than 3:12 (25 percent).

Roofing design shall follow the recommendations of the National Roofing Contractors Association (NRCA) as contained in NRCA publication, *NRCA Roofing and Waterproofing Manual.* The design of metal flashing, trim, and roofing shall follow the recommendations of the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) publication, *Architectural Sheet Metal Manual.*

There are also a large number of standards pertaining to roof systems, the majority of which have been developed by ASTM. The ASTM standards typically pertain to test methods (laboratory and field) and product standards, and are listed below:

- ASTM D6510, *Standard Guide for Selection of Asphalt Used in Built-up Roofing Systems*

- ASTM D6369, *Standard Guide to Design of Standard Flashing Details for Ethylene Propylene Diene terpolymer (EPDM) Rubber Roof Membranes*

- ASTM D5469, *Standard Guide for Application of New Spray-Applied Polyurethane Foam and Coated Roofing Systems*

- ASTM D5082, *Standard Practice for Application of Mechanically-Attached Polyvinylchloride (PVC) Sheet Roofing*

- ASTM D5036, *Standard Practice for Application of Adhered PVC Sheet Roofing*

- ASTM D3805, *Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings.*

There are also ANSI standards that pertain to roof systems, including:

- ANSI/SPRI RP-4, *Wind Design Standard for Ballasted Single-ply Roofing Systems*
- ANSI/SPRI ES-1, *Wind Design Standard for Edge Systems Used with Low-slope Roofing Systems*
- ANSI/SPRI FX-1, *Standard Test Procedure for Determining the Withdrawal Resistance of Roofing Fasteners*
- ANSI/SPRI RD-1, *Standard for Retrofit Roof Drains*.

Sustainable design criteria should be major factors in the selection process. At a minimum, the selected system should be thermally efficient, with consideration given to R-value, reflectivity, and emissivity. For those buildings that are intended to have a service life in excess of 20 years, a system with enhanced durability should be selected, to reasonably maximize the life of the roof in a life cycle cost-effective manner.

Traditional roofs of all types are vulnerable to bombardment with ultraviolet (UV) radiation emitted by the Sun. The mechanisms of decay vary, and can be summarized thusly:

- *Built-up roofing systems (asphalt)*—Bitumen at the surface is degraded through an oxidation reaction with visible light
- *Built-up roofing systems (coal tar)*—UV radiation and heat cause the oils and bitumen to separate, resulting in cracking of the bitumen
- *PVC membrane roofs*—Plasticizer migrates out of the membrane, leading to shrinkage, cracking, and/or shattering
- *EPDM membrane roofs*—UV radiation chemically scavenges the oily component, causing the membrane itself to shrink.

Resistance to UV attack for the above types of roofing systems can be achieved using a variety of coatings or shielding substances that are installed on the surface exposed to sunlight. These include carbon black (for EPDM membranes), factory-embedded mineral granules, metal foils, and/or field-applied reflective coatings.

4.12.1 Built-Up Roofs

Built-up roofs are composed of alternating layers of bitumen (either asphalt or coal tar) and reinforcement sheets (felts). Fiberglass felts are typically used for asphalt built-up roofs (BURs); however, polyester felts are also available. The asphalt is typically hot-applied; however, cold-applied asphalt is available (cold-applied asphalt incorporates solvent). The membrane is either adhered to the substrate in bitumen, or a base sheet (i.e., a heavy felt) is mechanically attached. When a BUR is installed over polyisocyanurate, NRCA recommends a suitable cover board be installed over the polyisocyanurate. Four plies of felt are recommended (if a nailed base sheet is installed, four plies are recommended in addition to the base sheet). "Heavy duty" fiberglass felts are available (ASTM E 2178 Type VI), but because of their stiffness, there is greater probability that unwanted voids be present in the finished membrane. Therefore, Type IV felts are recommended.

Exposed asphalt is susceptible to relatively rapid weathering. Therefore, BURs are surfaced with aggregate, a field-applied coating, or a mineral surface cap sheet. If aggregate is specified, wind blow-off should be considered. Coatings include aluminum-pigmented asphalt, asphalt emulsion (reflective or non-reflective), and acrylic. Coatings can enhance fire resistance, but will require periodic replacement (recoating). Therefore, because of future maintenance demands, coatings are not recommended. If a cap sheet is specified, it should be installed in addition to the four plies of felt.

ASTM D312, *Standard Specification for Asphalt Used in Roofing*, is the product specification for asphalt. There are four Type of asphalt. Type I is much more susceptible to flow than Type IV. ASTM D6510 provides guidance for selection of asphalt type in BURs. Base flashings are typically constructed with modified bitumen sheets. Although coal tar is still available, the vast majority of BURs are constructed with asphalt.

4.12.2 Membrane Roofs

Membrane roofing is a type of roofing system for buildings, which is used on flat or nearly flat roofs to prevent leaks and move water off the roof. Membrane roofs using fabricated synthetic rubber, thermoplastic (PVC or similar material), or modified bitumen ("torch down") shall be avoided wherever possible. Membrane roofing can be protected against UV degradation by filter fabric and ballast/pavers.

4.12.3 "Cool" Roofs

"Cool" roofs are engineered to maintain lower surface temperatures than non-cool roofs. Cool roofs are part of an interdependent system of exterior roofing surfaces, substrates, underlayments, configurations, ventilation, and insulation. By reflecting a large portion of the incident sunlight (and infrared radiation associated therewith) and releasing heat, summertime temperatures directly below the roof are substantially decreased, thus also reducing the building's overall cooling load. Many cool roofing products are also formed in ways that inhibit heat transfer through conduction, by allowing only minimal contact between the roof and the underlying structure. Additionally, because cool roofs release more heat than non-cool roofs, they can help reduce the heat island effect in urban environments.

"Cool" metal roofing is a family of sustainable, energy-efficient roofing products comprised of unpainted metal, pre-painted metal, and granular-coated metal. It is available in a wide variety of finishes, colors, textures, and profiles, for both steep-slope and low-slope applications. Depending upon the surface finish, cool metal roofing can provide enhanced energy efficiency with its solar reflectance and thermal emittance properties. In fact, the solar reflectance and infrared emittance of a metal roof can be engineered to meet the climate requirements of the building. Cool metal roofing can provide the desired high reflectance and low emittance in climates where heating loads prevail. Cool metal roofing can also provide the desired high reflectance and high emittance where cooling loads dominate. Cool metal roofing is usually conformant with the requirements of the EPA's/DOE's ENERGY STAR® program. ENERGY STAR-qualified roof products must meet minimum initial and aged solar reflectance values, as itemized in Tables 4-1 and 4-2:

Cool roofs should be conformant with DOE requirements released in the *Guidelines for Selective Cool Roofs, July 2010*. Requirements differ for low-sloped roofs and steep-sloped roofs. Low-sloped roofs have a pitch less than or equal to 9.5°, or a 2:12 rise over run, while steep-sloped roofs have a pitch greater than 9.5°.Roof products must meet minimum initial and aged solar reflectance and thermal emittance values, as itemized in Tables 4-1 and 4-2. According to DOE standards, as referenced in *ASHRAE 90.1*, new roofs must meet the additional requirement that they have a thermal resistance of at least R-30.

In addition, cool roof products must meet ENERGY STAR® product reliability requirements.For cool roof products, each company's warranty for reflective roof products must be equal in all material respects to the product warranty offered by the same company for comparable non-reflective roof products. A company that sells only reflective roof products must offer a warranty that is equal in all material respects to the standard industry warranty for comparable non-reflective roof products.

Table 4-1: DOE Specifications for Low-Slope Roof Products

Performance Characteristic	Current Criteria
4.12.3.1 Energy Efficiency	
Solar Reflectance [3-year aged]	Greater than or equal to 0.55
Thermal Emittance [new or aged]	Greater than or equal to 0.75
OR	
Solar Reflectance Index [3-year aged]	64

Table 4-2: DOE Specifications for Steep-Slope Roof Products

Performance Characteristic	Current Criteria
4.12.3.2 Energy Efficiency	
Solar Reflectance [3-year aged]	Greater than or equal to 0.20
Thermal Emittance [new or aged]	Greater than or equal to 0.75
OR	
Solar Reflectance Index [3-year aged]	16

Mill-finish metal roof systems have very high solar reflectance, providing further reductions in solar heat gain. Metal roofs with oven-cured, pre-painted organic coatings that incorporate new "cool pigment" technology offer high total solar reflectance and high infrared emittance even with darker colors. Emissivity as high as 90 percent can be achieved for painted and granular-coated roofing. Such pre-painted metal roofing products meet the reflectance requirements of all major energy code initiatives. Finally, unlike many roofing materials, metal's low thermal mass will not store heat and radiate it into the building in the evening hours. Painted metal roofs retain 95 percent of their initial reflectance and emittance over time.

EPA facilities can earn one LEED-NC 2009 point under the Sustainable Sites category by taking specific measures to reduce the heat island effect including increasing the reflectance index of roofing materials and/or installing a "green roof." Consult the LEED Reference Guide for specific criteria.

Cool metal roofing typically has a minimum recycled content of 25 percent and is 100 percent recyclable at the end of a long, useful life. Most metal roofs are credibly proven to last over 30 years with minimal maintenance.

4.12.4 Green Roofs

Green roofs, also known as vegetated roof covers or eco-roofs, are thin layers of living vegetation installed on top of conventional flat or sloping roofs. Green roofs protect conventional roof waterproofing systems while adding a wide range of ecological and aesthetic benefits. They are a powerful tool in combating the adverse impacts of land development and the loss of open space. Green roofs can reduce heating and cooling loads, and may reduce the need for insulation in warm, dry climates.

Green roofs are divided into two categories:

- Extensive green roofs, which are six inches or shallower and are frequently designed to satisfy specific engineering and performance goals

- Intensive green roofs, which may become quite deep and merge into more familiar on-structure plaza landscapes with promenades, lawn, large perennial plants, and trees.

All well-designed green roofs include subsystems responsible for:

- **Drainage**: Green roof drainage design must both maintain optimum growing conditions in the growth medium and manage heavy rainfall, without sustaining damage due to erosion or ponding of water

- **Plant nourishment and support**: The engineered medium must meet exacting requirements for grain size distribution, void ratio, moisture retention, etc.

- **Protection of underlying waterproofing systems**: Green roof assemblies must protect the underlying waterproofing system from incidental damage during maintenance activities and from roots and other biological attack.

The selection of a particular approach may depend on performance-related considerations, such as runoff control, drought tolerance, biodiversity, appearance, or accessibility to the public. While many pre-engineered systems are currently available, it is frequently necessary to customize these systems to satisfy specific performance objectives.

In all instances, materials, methods of installation, and quality assurance/quality control (QA/QC) procedures must be more stringent when green roof installation is involved**.** The structural engineer and landscape architect shall be involved in all design decisions. Waterproofing material that cannot withstand decades of root and biological attack unaided must be protected with a supplemental root-barrier layer. For information and standards pertaining to waterproofing materials, consult NCRA or ASTM publications.

In the U.S., green roof designs are generally regulated using existing standards for ballasted roofs. The International Code Council (ICC) code, formerly the Building Officials and Code Administrators International, Inc. (BOCA) code, used for guidance by many municipal authorities, recognizes roof gardens. It requires that the 'wet weight' of the green roof be treated as an additional dead load. It also supplies live load requirements for maintenance-related foot traffic and for regulated pedestrian access. One limitation of the ICC standards is that it does not specify the testing methods to be used in satisfying the code. ICC also provides standards for parapet heights and requirements for railings.

Additional guidelines for green roof construction have been developed by Forschungsgesellschaft Landschaftentwicklung Landschaftsbau. e.V. (FLL), in Germany (*Guidelines for Planning, Installation, and Maintenance of Green Roofs*). These standards and guidelines are comprehensive, and include industry standard tests for medium weight, moisture, nutrient content, grain size distribution, etc. The 2002 edition of the guide is available in English. FLL also certifies laboratories to conduct critical tests such as the root penetration resistance of waterproofing membranes. Many green roof products available in the United States have FLL certification.

In addition, ASTM has recently developed standards to establish a common basis for comparing fundamental green roof properties, such as maximum weight and moisture retention potential. ASTM standards related to green roofs include:

- ASTM E2396-05, *Standard Testing Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems*
- ASTM E2397-05, *Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems*
- ASTM E2398-05, *Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems*
- ASTM E2399-05, *Standard Test Method for Maximum Media Density for Dead Load Analysis (includes tests to measure moisture retention potential and saturated water permeability of media)*
- ASTM E2400-05, *Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.*

4.12.5 Roofing Accessories

Roof accessories are products, other than mechanical or structural, that are installed on or in roofing.

4.12.5.1 Roof Drainage

Dead level roofs are not permitted. Roof drains or scuppers are the only low points permitted. Provide a minimum slope to drains of 1:50 on roofing surfaces. When providing roof slope, consider sloping the structural roof deck, since over the life of the building this may be less expensive than providing insulation each time the roof is replaced. Roofs shall not be used to retain water. Downspouts shall be set plumb and not less than one inch from the wall. Leaders shall connect gutters on overhanging eaves to downspouts.

4.12.5.2 Insulation

Roof insulation should be installed in a minimum of two layers to ensure a sufficient thermal break in the roof system.

4.12.5.3 Skylights and Sloped Glazing

Skylights are defined as pre-fabricated assemblies shipped ready for installation, while sloped glazing is defined as field-assembled. Skylights design shall follow the guidelines of the AAMA Standard 1600. For the design of sloped glazing, two AAMA publications are available: *Glass Design for Sloped Glazing* and *Structural Design Guidelines for Aluminum Framed Skylights.* Skylights and sloped glazing should use low-e glass. Placement should be calculated to prevent glare or overheating in the building interior. Translucent panels may be required for daylighting applications, to avoid excessive heat gain during peak hours of the day; this must be balanced against the objective of admitting visible light and maintaining views to the outside. Another means of addressing this problem is to install light shelves, light pipes, louvers, and/or other reflectors to dissipate the intense visible light. If cost and space permit, reflectors/shelves can be motorized to follow the angle of solar rays and use feedback controllers to continually move the reflector component as the Sun’s tracking varies during the day.

Condensation gutters and a path for the condensation away from the framing should be designed. Consideration shall be given to cleaning of all sloped glazing and skylights, including access and equipment required for both exterior and interior faces.

4.12.6 Sheet Metal Flashings

Finished sheet metalwork will form a weather-tight construction without waves, warps, buckles, fastening stresses or distortion, which allows for expansion and contraction. The sheet metal mechanic is responsible for cutting, fitting, drilling, and other operations in connection with sheet metal required to accommodate the work of other trades. Coordinate installation of sheet metal items used in conjunction with roofing work to permit continuous roofing operations.

Details of sheet metalwork shall be shown on project drawings in accordance with the appropriate details in SMACNA's *Architectural Sheet Metal Manual*. Sheet metal color shall be long-lasting such as anodized aluminum, or baked enamel, and shall not be painted in the field. This does not preclude the use of natural materials like copper or aluminum when that is the choice of the designer. Avoid use of copper where drainage from the copper will pass over exposed masonry, stonework, or other metal surfaces.

4.12.7 Stacks, Vents, and Other Penetrations

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 properly rated for the specific application, and should be installed at the end of each duct system, such that all ducts within the occupied areas of a building are maintained under negative pressure. Hood exhaust should be designed in accordance with the guidelines in Chapter 6, Section 6.3 of this Manual.

4.12.8 Insulation

Roof insulation should be specified by thermal resistance (R value) necessary to obtain the required overall thermal transmittance (U value) for the roof. Thickness of insulation will vary with type of material furnished to provide a specified R value. When thickness of insulating material is governed by space limitations or construction features, the R value and corresponding thickness should be matched to the available space as closely as possible. Provide insulation of sufficient thickness to ensure that temperatures on vapor retarder surface (where vapor retarders are used) will be above the dew point temperature. The R value for insulation should never be less than the R value used in design of heating and/or air conditioning systems for the project.

Insulation should be a minimum of two layers to provide an adequate thermal break (i.e., minimize thermal short-circuiting through roof framing members).

Roof insulation shall have a flame spread rating not greater than 75 and a smoke developed rating not greater than 150, exclusive of covering, when tested in accordance with ASTM E84-09 (or latest version). Insulation bearing the "UL" label and listed in UL's *Building Materials Directory* (BMD) as meeting the flame spread and smoke developed ratings will be accepted in lieu of copies of test reports. Compliance with flame spread and smoke development ratings will not be required when:

- The insulation has been tested as part of a roof construction assembly of the type used for this project

- The construction is listed as fire-classified in the UL BMD or Class I roof deck construction in the FM Global, P7825, *Approval Guide*.

Insulation tested as part of a roof construction assembly shall bear UL or FM labels attesting to the ratings specified. Applicable regulatory requirements detailed in 16 CFR 1209 (Consumers Products Safety Commision, or CPSC) shall be followed, including those that address settled density, corrosiveness, critical radiant flux, and smoldering combustion.

Varieties of insulation are categorized by its composition, form, and functional mode, all of which shall be considered when specifying type and shall be in accordance with individual project requirements. Specified products shall be treated, installed and maintained in accordance with MSDS guidelines provided by the manufacturer. EPA requires that the regional climate, environmental impact, sustainability and cost effectiveness are taken into account by the project architect during the design specification phase. These considerations are required for a variety of reasons, one being that insulation can be a contributing factor to the success of preventing heat loss through a green roof. Refer to Section 4.12.4 for additional information on how insulation contributes to green roofs.

4.13 Building Support Areas

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/facility 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.

For laboratory facilities, appropriate loading dock/staging facilities are required relative to the facility's size, function, and material requirements. The truck turning radius to loading facilities should be appropriate to the truck size anticipated. Include dock leveling devices for accommodating different size trucks, where required. 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:

- Storage requirements and location for compressed gases (non-liquefied and liquefied) and cryogenic liquids
- Breakout area size
- The safe flow of bulk mail into the facility, including consideration of travel paths to and from protected, segregated, and ventilated mail receiving/screening areas
- 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 shall be also located near this zone to facilitate transportation and handling of explosive/flammable materials, toxic chemicals, and bio-hazardous waste before disposal at an off-site location by a licensed contractor.

4.13.1 Restrooms

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. Restrooms must conform to ABAAS and/or UFAS requirements, as applicable. All public toilet rooms shall be located along an accessible path of travel, but not in any non-secure areas. These facilities should also not be situated adjacent to the queuing/security screening area at the public entrance.

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. The toilet fixture schedule is specified in Table 4-3 below, and shall be applied to each full floor based on one person for each 135 square feet (ft^2) of office space in a ratio of 50 percent men and 50 percent women.

Table 4-3: Required Number of Water Closets and Lavatories

Number of Men*/Women	Water Closets	Lavatories
1 – 15	1	1
16 – 35	2	2
36 – 55	3	3
56 – 60	4	3
61 – 80	4	4
81 – 90	5	4
91 – 110	5	5
111 – 125	6	5
126 – 150	6	**
> 150	***	

Source: U.S. GSA, Publication P-100

* In Men's facilities, urinals may be substituted for 1/3 of the water closets specified.

** Add one lavatory for each 45 additional employees over 125.

*** Add one water closet for each 40 additional employees over 150.

Newly-installed toilet partitions shall conform with the applicable EPA CPG, as indicated in Table 4-4 below:

Table 4-4: EPA CPGs for Restroom Dividers/Partitions[1]

Material	Minimum Post-Consumer Content (%)	Total Recovered Materials Content (%)
Steel (manufactured by the BOF process)	16	25 – 30
Steel (manufactured by the EAF process)	67	100
Plastic	20 – 100	20 – 100

1. Source: EPA CPG dated September 4, 2008.

CPG – Comprehensive Procurement Guideline; BOF – basic oxygen furnace; EAF – electric arc furnace

All sanitation finishes shall be non-permeable, non-corrosive, and easily maintainable. The toilet room shall have at least one towel rack, towel dispenser, or other dispensers, convenience shelf or shelves (e.g., for files and folders), 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. There should be men and women restrooms with 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.

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. Wheelchair-accessible urinals shall be provided in the quantities required by Section F213 of ABAAS and to the following specifications: Provide a large-diaphragm (not less than 2.625 inches upper chamber inside diameter at the seal between upper and lower chambers), nonhold-open flush valve conforming with ASTM B584, including vacuum breaker and angle (control-stop) valve with back check. Provide concealed chair carriers conforming with ASTM A112.6.1M. Mount the urinal with the front rim a maximum of 17 inches above the floor and the flush valve handle a maximum of 44 inches above the floor, for use by disabled persons in a wheelchair.

Water closets and urinals shall not be visible when the toilet room entry door is open. Low-flow fixtures must be specified when installing faucets, urinals, toilets, and shower heads. Refer to Chapter 6, Section 6.10.2 for more information on low-flow fixtures.

Restrooms shall be equipped with exhaust ventilation to the outside. Emergency lighting shall be provided in each restroom.

4.13.2 Equipment Spaces

Mechanical and electrical equipment rooms must be designed with adequate aisle space and clearances around equipment to accommodate maintenance and replacement. Hoists, rails and fasteners for chains should be provided to facilitate removal of heavy equipment. A minimum of four percent of the typical floor's gross floor area shall be provided on each floor for air handling equipment. A minimum of one percent of the building's gross area shall be provided for the central heating and cooling plant (location to be agreed upon during preparation of concept submission.)

Mechanical equipment rooms shall have not less than 12 feet height clearance. All mechanical equipment rooms must be accessible via a freight elevator at that level for the purpose of operations and maintenance, and replacement of equipment. The freight elevator must be of a size to accommodate the largest component of the equipment. Ship's ladders are not permitted as a means of access to mechanical equipment. All equipment spaces must be designed to control noise transmission to adjacent spaces.

Mechanical rooms shall open from non-occupied spaces, such as corridors. If mechanical rooms must open from occupied spaces because of configuration constraints, consider incorporating a vestibule with partitions that extend to the nearest structural walls, with sound-gasketed doors at each side for acoustic and vibration separation. Refer to Chapter 6, Section 6.2.8 for additional mechanical room requirements.

The main electrical switchgear shall not be below toilets or janitor closets, or at an elevation that requires sump pumps for drainage. If electrical switchgear is housed in the basement, provisions shall be made to prevent water from flooding the electrical room in the event of a pipe breaking. Automatic sprinkler piping shall not be installed directly over switchgear equipment.

The architect shall coordinate with the mechanical engineer to place mechanical equipment in order to optimize access for maintenance and replacement. Design of equipment placement shall allow maintenance of motors and replacement of filters from the ground. When there is no practicable alternative and equipment must be placed overhead, replacement of filters shall require a standard step ladder requiring one person to safely operate.

Public and employee entrances should include space for possible future installation of access control and screening equipment.

4.13.3 Maintenance Shops

Walls and ceilings of all equipment and maintenance shops should be gypsum board, concrete masonry surfaces, or other durable surfaces; exposed batt or other forms of insulation should not be used at wall surfaces. Walls in these areas shall be painted.

Floors in mechanical rooms and maintenance shops shall be waterproofed. Floors in electrical and communications rooms shall be painted or sealed. Communications equipment rooms may also have resilient flooring. Rooms containing major electrical or environmental equipment must be designed to provide clearance for service including replacement of components or the entire piece of equipment.

4.13.4 Locker Rooms

Locker rooms shall be finished spaces. The shower area shall be separated from the locker area. Regular gypsum wallboard is not to be used as a substrate for any shower room surface. Low flow shower heads should be installed in all shower rooms. Staff locker rooms shall be provided with resilient flooring and water-resistant wall covering(fiber), except in “wet” areas, which should be finished similar to general use toilets (ceramic tile floor and walls).

4.13.5 Food Service Areas

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 are as follows:

- 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 co-mingled bottles and cans
- Refrigeration units should be ENERGY STAR labeled.

Refer to Chapter 6 for additional information on food service equipment.

4.13.6 Security Control Centers

The security control center should be located adjacent to the main entrance and lobby. A minimum of 225 ft^2 shall be allocated for this room, which is intended to house the command station for the security guards and their equipment for current and future building needs. There should be an expectation in the planning of the building that a security command center and inspection station may be needed in the future, if it is not required at time of building design.

The security control center and operational control center may be co-located. If co-located, the chain of command shall be carefully pre-planned to ensure the most qualified leadership is in control for specific types of events. EPA will provide secure information links between the security control center, operational control center, and fire command center. A backup control workstation should be provided in a different location, such as a manager's or engineer's office. If feasible, an off-site location shall be considered. A fully redundant backup control center shall be installed for critical facilities, as determined by EPA.

4.13.7 Chemical Storage Areas

Chemical storage shall be provided and be in compliance with the requirements of the EPA Facilities Manual, Volume 3, Section 4.6 (*Chemical Storage and Management*). Chapter 4 of the Safety Manual. Below are some general guidelines:

- Only authorized personnel will be permitted entry into limited access or exclusion areas where chemicals are housed. Control procedures should assure positive identification of all personnel prior to entry

- Exterior inspections of all structures containing chemicals should be conducted periodically for signs of tampering and covert entry. The results of the inspection will be annotated in the guard force log or other suitable form

- Doors used for main access to chemical agent storage structures should be locked with two high-security locks. Each high-security lock should be mounted on a high-security, shrouded hasp

- All doors and locks opening(in excess of 96 square inches) should be equipped with intrusion detection system (IDS) coverage

- Perimeter lighting will be positioned and designated to enable the detection of persons in the entire clear zone, inside the inner perimeter fence, between the fences, and outside the outer perimeter fence

- Lighting fixtures will be positioned to avoid blinding of guards from glare and silhouetting

- Fresh air intakes shall be provided in conformance with Chapter 6, Section 6.4.5 of this Manual.

4.13.8 General Storage Areas

General storage is usually required on every floor. Adequate storage space must not be overlooked in the design, especially considering typical difficulties in resolving equipment disposition and maintaining inventories of essential substances (e.g., in laboratories). Additional issues to resolve are as follows:

- Locate storage internal to the building, maximizing underused space for occupied functions

- Ensure good access to service elevator(s)

- 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 the program(s) being served

- Ensure space to collect corrugate cardboard, office paper, and commingled beverage containers for recycling (additional recyclables may be added, and adequate space thus must be supplied).

4.13.9 Fitness Centers

Fitness centers provide space designated for exercise, fitness training, and physical wellness activities. A minimum 12-foot ceiling height is generally required in this space type, to accommodate the clearances needed for daily equipment usage. Special surfaces are also required for many athletic activities, such as cushioned training surfaces, mirror walls, or impact-resistant walls. Anticipate circulation, in particular controlled circulation, using a flow diagram at the beginning of the design process. Increase ventilation in locker rooms and fitness centers, for moisture control, air quality, temp control.

Increased structural steel is typically provided to reduce vibration transmission. Exercise and weight rooms, including equipment storage rooms, should be designed for a 150 pounds per square foot (lb/ft^2) live load. Finishes should be durable and easy to maintain in anticipation of maximum use. Reduce noise impact generated by physical activity, by including sound baffles at all acoustically rated partitions, in particular, those in exercise and weight rooms.

4.13.10 Bicycle Storage Facilities and Showers

In order to encourage the use of alternative modes of transportation by EPA employees, design the building with transportation amenities such as bicycle racks and showering/changing facilities. Bicycle usage as an alternative transportation mode aids in the reduction of air pollution and greenhouse gas (GHG) emissions from transportation.

EPA facilities can earn one Sustainable Sites point toward LEED-NC 2009 certification if they provide bicycle parking and showers/changing facilities for building occupants. Check the LEED Reference Guide for specific requirements (number of bicycle racks, etc.)

4.13.11 Recyclables Accumulation/Storage Areas

In order to facilitate the reduction of waste generated by building occupants that is typically disposed of in landfills, recycling infrastructure shall be provided to building tenants. Provide an easily accessible area that serves the entire building and is dedicated to the collection and storage of non-hazardous materials for recycling, including (at a minimum) paper, corrugated cardboard, glass, plastics, and metals. Coordinate the size and functionality of the recycling areas with the anticipated collection services for glass, plastic, office paper, newspaper, cardboard, and organic wastes (as applicable), to maximize the effectiveness of the dedicated areas. Consider employing cardboard balers, recycle CFL bulbs, recycling chutes, scale to weigh material, and collection bins at individual workstations to further enhance the recycling program.. (Specifications for cardboard balers are provided in Chapter 6, Section 6.11.3.)

EPA facilities are required (i.e., by prerequisite) to set aside sufficient storage space for recyclables (e.g., paper, cardboard, glass, metal, and plastic) to become LEED-NC 2009 certified. Equipment such as balers, can crushers, etc. reduces the volume of recyclables and therefore aids in maximizing available on-site storage space.

In addition to recycling dispensers and collection services space requirements, accommodate recycling area for scales and measuring devices in order to track recycling data. Separate floor scales for weighing 55-gallon drums of hazardous waste may be required for certain facilities.

4.14 Security and Safety Architectural Requirements

4.14.1 Locks

Locks are the most acceptable and widely used security devices for protecting facilities, classified materials, and property. Key locks consist of, but are not limited to, the following:

- Cylindrical locksets are often called key-in-knob or key-in-lever locks. They are normally used to secure offices and storerooms. The locking cylinder located in the center of the doorknob distinguishes these locks. Some cylindrical locksets have keyways in each of the opposing knobs that require a key on either side to lock and unlock them. Others unlock with a key, but may be locked by pushing or rotating a button on the inside knob. These locks are suitable only for very low-security applications. Using these locks may require compensatory measures, in the form of additional locks on containers within the room

- Dead-bolt locks are sometimes called tubular dead bolts. They are mounted on the door in a manner similar to cylindrical locksets; the primary difference is in the bolt. When the bolt is extended (locked), the dead bolt projects into the doorframe at least one inch, and it cannot be forced back (unlocked) by applying pressure to the end of the bolt. The dead-bolt lock has the potential for providing acceptable levels of protection for storerooms and other areas where more security is desired

- Mortise locks are so named because the lock case is mortised or recessed into the edge of the door. The most common variety of mortise locks has a doorknob on each side of the door. Entrance doors often have an exterior thumb latch rather than a doorknob. The mortise lock can be locked from inside by means of a thumb turn or by a button. Mortise locks are considered low-security devices since they weaken the door in the mortised area

- Drop-bolt locks (often referred to as “jimmy-proof” locks) are normally used as auxiliary locks, similar to dead bolts. Both the drop-bolt lock body and the strike have interlocking leaves similar to a door hinge. When closed, locking pins in the lock body drop down into the holes provided in the strike and secure the locking system. Since the lock body and the strike are interconnected with locking pins when closed, the lock essentially becomes a single unit and is extremely difficult to separate

- Rim-cylinder locks are mounted to the door's inside surface and are secured by screws in the door face. These locks are generally used with drop-bolt and other surface-mounted locks and latches. They consist of an outer barrel, a cylinder and ring, a tailpiece, a back mounting plate, and two mounting screws. The tailpiece screws are usually scored so that the lock can be tailored to fit varying door thicknesses

- Mechanical, push-button combination locks are digital (push buttons numbered one through nine), combination door-locking devices used to deny area access to any individual not authorized or cleared for a specific area. These locks are normally used for access control and should be backed up by door-locking devices when the facility is unoccupied

- Padlocks are detachable locks that are typically used with a hasp. Low-security padlocks, sometimes called secondary padlocks, are used to deter unauthorized access, and they provide only minimal resistance to force. Low-security locks are made with hardened steel shackles. Precautions must be taken to avoid confusing these locks with similar brass or bronze locks. The brass or bronze locks are commonly used but do not meet the security requirements of the hardened shackled locks. High-security padlocks may be used to secure arms, ammunition, and explosives. They provide the maximum resistance to unauthorized entry when used with a high-security hasp.

4.14.2 Forced Entry

The project design shall follow the requirements of the standards listed below:

- ASTM F476, *Security of Swinging Door Assemblies*
- ASTM F842, *Standard Test Methods for Measuring the Forced Entry Resistance of Sliding Door Assemblies, Excluding Glazing Impact.*

A medium protection level (per UFC 4-020-01FA through 4-020-04FA) for walls would be the equivalent of four inches of concrete with Number Five (No. 5) reinforcing steel at six-inch intervals each way, or eight inches of vibrated in place concrete (CMV) with No. 4 reinforcing steel at 8 in. medium and high protection levels.

4.14.3 Windows

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, requires that external windows and glass doors be designed and/or treated to prevent flying glass fragments during an explosion. Window glazing materials typically used to meet this requirement include:

- Thermally-tempered, heat-resistant, or annealed glass with a security film installed on the interior surface and attached to the frame
- Laminated, thermally-tempered glass
- Laminated, heat-strengthened glass
- Laminated, annealed glass.

Window materials such as untreated, monolithic annealed glass; untreated heat-strengthened glass, and wire glass shall not be used without specific permission from the EPA project manager. Where used, the minimum acceptable blast film thickness shall be four-mil (0.004 inch or 0.1 mm) thick Mylar® film applied on the interior surface of the window or through use of laminated glass. Window glazing shall be selected such that normal tools carried by firefighters (e.g., pick head axe, Halligan tool) can readily overcome the glazing barrier.

Table 8-1 of GSA P100 may be used as guidance when determining glazing protection levels based on glass fragmentation, including the acceptable maximum distance glass shards would travel in the event the glazing integrity is compromised.

4.14.4 Progressive Collapse

Refer to Chapter 5 of this Manual for progressive collapse specifications.

4.14.5 Public Service Areas

Public service areas or access to an elevator shaft should not be located in any non-secure areas.including screening at the public entrance and then the queuing area..”Non-secure” areas include reception and badging desks at the facility entrance and the associated queuing area(s) to enter the building.

4.14.6 Loading Docks and Receiving Areas

The loading docks and receiving and shipping areas design should limit damage to adjacent areas and, under an attack scenario, vent explosive force to the exterior of the building as best as possible. The areas adjacent to the loading dock and receiving and shipping do not need to be designated for blast resistance if the area below is not occupied and contains no critical utilities.

4.14.7 Stairways and Exit Signs

Self-contained battery LED lighting should be provided in stairways and for exit signs. Floor-level evaluation lighting systems should be considered, since an emergency event may fill corridors with dense smoke.

4.14.8 Mailrooms

The mailroom should be located away from facility main entrances, areas containing critical services, utilities, distribution systems, and important assets. In addition, the mailroom should be located at the perimeter of the building with an outside wall or window designed for pressure relief. It should have adequate space for explosive disposal containers. It is preferable to have the mailroom located near the loading dock.

4.14.9 Exterior Entrances

The entrance design must balance aesthetic, security, risk, and operational considerations. One strategy is to consider co-locating public and employee entrances. Entrances should be designed to avoid significant queuing. If queuing will occur within the building footprint, the area should be enclosed in blast-resistant construction. If queuing is expected outside the buildings, conflicts may arise if the design alters the exterior or lobby configuration in a historic structure. Consult the Regional Historic Preservation Officer regarding appropriate solutions.

4.14.10 Co-located Entrances

Combine public and employee entrances where possible.

4.14.11 Garage and Vehicle Entrances

All garage or service area entrances (for Government-controlled or employee vehicles with permits) that are not otherwise protected by site perimeter barriers shall be protected by devices capable of arresting a vehicle of the designated threat size at the designated speed. This criterion may be lowered if the access circumstances prohibit a vehicle from reaching this speed.

4.14.12 Areas of Concealment

To reduce the potential for concealment of devices before screening points, avoid installing features such as trash receptacles and mail boxes that can be used to hide devices. If mail or express boxes are used, the size of the openings should be restricted to prohibit insertion of packages.

4.14.13 Roof Access

Design locking systems and other countermeasures to restrict roof access to authorized personnel only. The A/E shall coordinate with the local fire marshal for roof access requirements and locking of doors that provide access to the roof.

4.14.14 Bio-safety in Microbiological and Biomedical Laboratories

EPA has facilities with up to Bio-safety Level 3 (BSL-3) capabilities (defined below). Any such facilities shall be constructed and operated in accordance with U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC), *Bio-safety in Microbiological and Biomedical Laboratories*.

Bio-safety Level 3 facility design and construction are applicable to clinical, diagnostic, teaching, research, or production facilities in which work is done with indigenous or exotic agents:

- With a potential for respiratory transmission
- Which may cause serious and potentially lethal infections.

Mycobacterium tuberculosis, St. Louis encephalitis virus, and *Coxiella burnetii* are representative of the microorganism assigned to this level. Primary hazards to personnel working with these agents relate to auto-inoculation, ingestion, and/or exposure to infectious aerosols.

At BSL-3, more emphasis is placed on primary and secondary barriers (compared with BSL-1 and BSL-2) to protect personnel in contiguous areas, the community, and the environment from exposure to potentially infectious aerosols. For example, all laboratory manipulations shall be performed in a biological safety cabinet (BSC) or other enclosed equipment, such as a gas-tight aerosol generation chamber. Secondary barriers for this level include controlled access to the laboratory and ventilation requirements that minimize the release of infectious aerosols from the laboratory.

The following design requirements for secondary barriers are mandatory for BSL-3 facilities:

- The laboratories where Level 3 agents are being handled must be separated from areas that are open to unrestricted traffic flow within the building, and access to these laboratories must be restricted. Passage through a series of two self-closing, lockable doors is the basic requirement for entry into the laboratory from any access corridor. A clothes change room may be included in the passageway
- Each laboratory room must contain a sink for hand washing. The sink shall be "hands free" or automatically operated and shall be located in proximity to the room exit door
- The interior surfaces of walls, floors, and ceilings of areas where BSL-3 agents are handled must be constructed for easy cleaning and decontamination. Seams, if present, must be sealed. Walls, ceilings, and floors should be smooth, impermeable to liquids, and resistant to the chemicals and disinfectants normally used in the laboratory. Floors should be monolithic and slip-resistant. Consideration shall be given to the use of coved floor coverings. Penetrations in floors, walls, and ceiling surfaces must be sealed. Openings (e.g., those around ducts and spaces between doors and frames) shall be capable of being sealed to facilitate decontamination
- Bench tops shall be impervious to water and resistant to moderate heat and the organic solvents, acids, alkalis, and other chemicals that may be used to decontaminate the work surfaces and equipment

- BSCs are required and shall be located away from doors, room air supply louvers, and heavily-traveled laboratory areas

- An eyewash station shall be readily available within the laboratory

- Illumination on work surfaces shall be adequate for all research activities, avoiding reflection and glare that could impede vision

- During initial commissioning, the facility must be tested to verify that the design and operational parameters necessary for BSL-3 status have been met prior to commencement of routine operations. Facility performance shall be verified at least annually.

Refer to Chapter 6 of this Manual for additional information.

4.15 Deconstruction and End-of-Life Structure Management

The facility design should incorporate end-of-life waste prevention strategies for future rebuilds or demolition, such as the following:

- Using modular components

- Designing to standard material sizes

- Considering prefabricated components

- Specifying mock-ups for tricky, repetitive details

- Planning for anticipated changes

- Material recycling of any construction/demolition waste (at a minimum: wood, metals, and paper).

5. STRUCTURAL REQUIREMENTS

5.1 General Requirements

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 buildings and building systems constructed of concrete, masonry, steel, wood, or and other suitable materials
- All other substructures and superstructure elements that are proportioned on the basis of stress, strength, and deflection requirements.

5.1.1 Compatibility Requirements

Material and details shall be compatible with the following:

- Clear space and span requirements
- Serviceability requirements
- Applicable construction type, applicable local building code, and/or NFPA 220, *Standards of Type of Building Construction,* 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
- EPA's CPG requirements and recommendations, as appropriate.

5.1.2 Design Personnel Qualifications

The person with overall responsibility for the final structural design shall be a registered Professional Engineer (P.E.) in the state where the project will be completed, and all final design drawings shall be sealed by a registered P.E. Structural engineers shall have a certified Structural Engineer (S.E.) license, as appropriate (as of May 2009, required for all projects in Illinois, as well as some projects in California, Nevada, Oregon, and Utab). For additional information, consult the National Council for Engineering and Surveys (NCEES).

5.1.3 Design 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.

5.1.3.1 Dead Loads

Dead loads are loads that remain permanently in place. They 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, such 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 plf, 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 the live-load factors required by the applicable building code.

The unit weights of materials and construction assemblies for buildings and other structures shall be those given in American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) Standard 7-05, *Minimum Design Loads for Buildings and Other Structures*. 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, ventilation, and air conditioning (HVAC) equipment; electrical equipment; flues; fire sprinkler piping and valves; and similar fixed equipment. The weight of service equipment that may be removed with change of occupancy of a given area shall be considered as live load.

5.1.3.2 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 a live load. The Project Structural Engineer must determine any special requirements for floor loading in accordance with national and local building codes, and work with the agencies having jurisdiction to produce an approvable design.

Analysis in the early planning stages of a project is required to establish the loadings for specific pieces of equipment, to verify that these equipment loads do not exceed the design floor loads. The timing and sequencing that the equipment is placed into the building must be considered, as 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 (except where specifically required by EPA).

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/SEI Standard 7-05 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/SEI Standard 7-05, or as required by local building codes, whichever is more stringent. Live loads on roofs shall include the minimum roof live loads, 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 compensate for one re-roofing in the future. If a planted (i.e., “green”) roof is being considered as a sustainable design feature, the load for the roofing system (supports, planters, etc.) 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.

5.1.3.3 Wind Loads

Wind load designs for building and other structures shall be determined in accordance with the procedures in ASCE/SEI Standard 7-05, or local codes, whichever is more stringent, using site-specific basic wind speeds. Exposure “C”, as defined in ASCE/SEI Standard 7-05, 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, 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 evaluated.

5.1.3.4 Other Loads

Other load requirements are as follows:

- **Equipment Supports:** Equipment supports shall be designed to prevent 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 or other measures to reduce the dynamic transmission of the applied load. Vibrations and resonance are critical design issues because of safety and worker comfort considerations, and as such may require additional funding allocations in order for the area or facility to remain in operation.

- **Foundation and 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.

- **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.

- **Temperature Changes**: The design of structures shall include the effects of stresses and associated displacements resulting from variations in temperature. The diurnal and seasonal variations in temperatures to which structural elements will be exposed shall be determined for the localities in which the structures are to be built. Structures shall be designed to inhibit or accommodate displacements resulting from the maximum seasonal temperature change, with no compromise in integrity.

- **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 inches 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.

- **Vibration-Sensitive Equipment:** The Project Structural Engineer and Project Mechanical Engineer shall be responsible for verifying the requirements for installation of vibration-sensitive equipment in all laboratory areas. The structural system in laboratory areas shall be designed to accommodate and control specific, highly-localized frequency loads and vibration inputs from the general building systems to these sensitive areas. Five control measures must be pursued where necessary to eliminate vibrations:

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

    - Identification and isolation of particular services that involve operating speeds close to the natural frequencies of the floor and equipment supports

    - Identification and additional isolation of sources that, although they do not match the operating speed of equipment and primary structural response frequencies, may produce sufficient vibration to cause a threat to the building (or to specific components and sub-assemblies) and/or disruption to on-site personnel

    - Identification and 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.

- **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.

- **Green Roofs:** As discussed in Section 4.12, the project structural engineer shall ensure that, where applicable, the roof can adequately support the excess dead load and transmitted live loads associated with a green roof.

5.1.4 Calculation Methodologies and Models

All design (including calculations) shall be performed and checked by a structural engineer registered in the state in which the project is located. 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. Computer software used for structural analysis and design shall be from a nationally recognized vendor.

5.1.5 Reducing Vulnerability of Key Structural Elements

These criteria are intended to reduce the potential for structural damage and resulting personnel injuries. The Project Structural Engineer should exercise good judgment when applying these criteria to ensure the integrity of the structure, and to obtain the greatest level of protection practicable, given:

- Project technical constraints
- Life cycle cost constraints
- Criticality of the asset to be protected
- Degree of environmental, health, and/or safety risk in the event of damage/destruction.

There are three basic approaches to blast resistant design: (1) blast loads can be reduced (primarily by increasing standoff distance); (2) the facility can be strengthened; or (3) higher levels of risk can be accepted. The best solution is often a combination of the three. In general, the field of protective design is the subject of a great deal of ongoing research and testing. These design criteria will be updated as new information is made available.

5.1.5.1 Designer Qualifications

For buildings designed to meet Medium or Higher Protection Levels, a blast engineer must be included as a member of the design team. The individual/firm should have formal training in structural dynamics, and demonstrated strong experience with accepted design practices for blast-resistant design. A technical peer group should evaluate new and untested design methods.

5.1.5.2 Good Engineering Practice Guidelines

The following constitute a brief summary of what are currently considered good engineering practices to combat potential progressive collapse. Due to extensive and ongoing research in this field, it is expected that new guidelines will be issued from time to time. These should be used as guidelines only and are not prescriptive requirements:

- For higher levels of protection from blast, cast-in-place reinforced concrete is normally the construction type of choice. Other types of construction such as properly designed and detailed steel structures are also allowed.
- To economically provide protection from blast, inelastic or post-elastic design is standard. This allows the structure to absorb the energy of the explosion through plastic deformation while achieving the primary objective of saving lives. To design and analyze structures for blast loads, which are highly non-linear both spatially and temporally, it is

essential that proper dynamic analysis methods be used. Static analysis methods will generally result in unachievable or uneconomical designs.

- The designer should recognize that components might act in directions for which they are not designed. This is due to the engulfment of structural members by blast, upward and inward loading of elements, and dynamic rebound of members. Making steel reinforcement (positive and negative faces) symmetric in all floor slabs, roof slabs, walls, beams, and girders will generally address this issue. Symmetric reinforcement also increases the ultimate load capacity of the members.

- Lap splices should fully develop the capacity of the reinforcement and should be staggered.

- Ductile detailing should be used for connections, especially primary structural member connections.

- There should be control of deflections around certain members, such as windows, to prevent premature failure. Additional reinforcement is generally required.

- Balanced design of all building structural components is desired. For example, for window systems, the frame and anchorage shall be designed to resist the full capacity of the weakest element of the system.

- Special shear reinforcement, including ties and stirrups, is generally required to allow large post-elastic behavior. The designer should carefully balance the selection of small but heavily reinforced (i.e., congested) sections and larger sections with lower levels of reinforcement.

- Connections for steel construction should be ductile and develop as much moment connection as practical. Connections for cladding and exterior walls to steel frames shall develop the capacity of the wall system under blast loads.

- In general, single-point failures that can cascade, producing widespread catastrophic collapse, are to be avoided. A prime example is the use of transfer beams and girders that, if lost, may cause progressive collapse and are therefore highly discouraged.

- Redundancy and alternative load paths are generally useful in mitigating blast loads. One method of accomplishing this is to use two-way reinforcement schemes, where possible.

- In general, column spacing should be minimized so that reasonably-sized members can be designed to resist the design loads and increase the redundancy of the system. A practical upper level for column spacing is generally 30 feet for the levels of blast loads described herein.

- In general, floor-to-floor heights should be minimized. Unless there is an overriding architectural requirement, a practical limit is generally less than or equal to 16 feet.

- It is recommended that the designer use fully grouted and reinforced CMU construction in cases where CMU is selected.

- It is essential that the designer actively coordinate structural requirements for blast with other disciplines, including architectural and mechanical.

- The use of one-way wall elements spanning from floor-to-floor is generally a preferred method to minimize blast loads imparted to columns. In many cases, the ductile detailing requirements for seismic design and the alternate load paths provided by progressive collapse design assist in blast protection. However, the designer must bear in mind that these design approaches may result in conflicts that should be resolved on a case-by-case basis, using sound engineering judgment and experience.

- At a minimum, all new facilities shall be designed for the loss of a column for one floor above grade at the building perimeter without progressive collapse. This is intended to ensure adequate redundant load paths should damage occur for whatever reason. Designers may apply static and/or dynamic methods of analysis to meet this requirement. Ultimate load capacities may be assumed for the analysis.

5.1.5.3 Structural and Non-Structural Elements

To address blast, the priority for upgrades should be based on the relative importance of a structural or non-structural element, in the order defined below:

- **Primary Structural Elements** – The essential parts of the building's resistance to catastrophic blast loads and progressive collapse, including columns, girders, roof beams, and the main lateral resistance system.

- **Secondary Structural Elements** – All other load-bearing members, such as floor beams and slabs.

- **Primary Non-Structural Elements** – Elements that are essential for life safety systems or elements that can cause substantial injury if failure occurs, including ceilings of heavy suspended mechanical units.

- **Secondary Non-Structural Elements** – All elements not covered in primary non-structural elements, such as partitions, furniture, and light fixtures.

Priority should be given to the critical elements that are essential to mitigating the extent of the collapse. Designs for secondary structural elements should minimize injury and damage. Consideration should also be given to reducing damage and injury from primary, as well as secondary, non-structural elements.

5.1.5.4 Forced Entry

A minimum protection level (per U.S. Department of Army, *Security Engineering* technical manual [TM] 5-853) for walls would be the equivalent of four-pound concrete with No. 5 reinforcing steel at six-inch intervals each way, or eight-inch CMU with No. 4 reinforcing steel at eight-inch intervals. TM 5-853 provides other alternatives for low, medium and high protection.

5.1.5.5 Other Resources and References

Design and analysis approaches should be consistent with those in the technical manuals below:

- U.S. Air Force Engineering and Services Center, ESL-TR-87-57, *Protecting Buildings from Bomb Damage: Transfer of Blast-Effects Mitigation Technologies from Military to Civilian Applications*

- U.S. Department of the Army*,* TM 5-855-1, *Design and Analysis of Hardened Structures to Conventional Weapons Effects*
- U.S. Department of the Army, TM 5-853 and Air Force, AFMAN 32-1071, *Security* Engineering, Volumes 1, 2, 3, and 4
- U.S. Department of the Army, TM 5-1300; U.S. Navy, NAVFAC P-397; and U.S. Air Force, AFR 88-2, *Structures to Resist the Effects of Accidental Explosions*
- U.S. Department of Energy, *A Manual for the Prediction of Blast and Fragment Loading on Structures*
- U.S. General Services Administration, PBS-P100, *Facilities Standards for the Public Buildings Service.*

5.1.6 Seismic Design

All buildings shall meet, at minimum, meet all requirements laid forth in:

- The International Building Code (IBC) (latest edition)
- The Interagency Committee on Seismic Safety in Construction (ICSSC) publication *Standards of Seismic Safety for Existing Federally Owned and Leased Buildings*, National Institute of Standards and Technology, 2002 (or latest edition)
- The 2009 National Earthquake Hazard Reduction Program (NEHRP) publication *Recommended Seismic Provisions for New Buildings and Other Structures* (or latest edition); and
- For existing buildings, American Society of Civil Engineers (ASCE) 41, *Seismic Rehabilitation of Existing Buildings*.

Refer to Chapter 2, *Planning and Siting*, for evaluating seismic activity at a particular location.

5.1.6.1 Seismic Instrumentation for Buildings

New and existing buildings located in Regions of High Seismicity, greater than six stories in height, and having an aggregate floor area of 60,000 square feet or greater (and every building located in Regions of High Seismicity over 10 stories in height regardless of floor area) shall be provided with United States Geological Survey (USGS) approved recording accelerographs. The USGS has developed guidelines and a guide specification for the seismic instrumentation of Federal buildings (refer to M. Celebi, *Seismic Instrumentation of Buildings*, USGS Open-File Report 00-157, April 2000).

5.1.7 Progressive Collapse

At a minimum, all new facilities shall be designed for the loss of a column for one floor above grade at the building perimeter without progressive collapse. This design and analysis requirement for progressive collapse is not part of a blast analysis. Rather, it is intended to ensure adequate redundant load paths in the structure should damage occur for whatever reason. Designers may apply static and/or dynamic methods of analysis to meet this requirement. Ultimate load capacities may be assumed in the analyses.

Guidelines for designing buildings to resist progressive collapse can be found in the following publications:

- GSA PBS P-100, Chapter 8, Section 8.4
- GSA, *Progressive Collapse and Design Guidelines for New Federal Office Buildings and Major Modernization Projects,* 2003
- ASCE 7-02, *Minimum Design Loads for Buildings and Other Structures*, 2002 (or latest version)
- ACI 318-02, *Building Code Requirements for Structural Concrete*
- U.S. Department of Defense, *Design of Buildings to Resist Progressive Collapse*, UFC 4-023-03, July 2009.

5.1.8 Geotechnical/Foundation

The provisions of the local governing building code shall be the minimum requirements for foundation design. The potential adverse effects of frost heave and displacements 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, and determining seismic potential and differential settlement.

5.1.8.1 Concrete Slab

Where concrete slab-on-grade construction is used, the slab shall be placed on a capillary water barrier overlying a compacted sub-grade. 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.

Refer to Section 3.11 of this Manual for additional information on geotechnical design requirements.

5.2 Relevant Codes and Standards

Refer to the following list of relevant codes and standards adopted by EPA for the use of concrete, masonry, steel, and other materials:

5.2.1 Concrete Codes

Concrete materials, design, and construction for buildings and other structures shall comply with:

- American Concrete Institute (ACI) 318-08, *Building Code Requirements for Structural Concrete*
- ACI 301-05, *Specifications for Structural Concrete*
- ACI 117-06, *Specifications for Tolerances for Concrete Construction and Materials*
- ACI 305R/306R-06, *Hot Weather Concreting*

- Pre-cast/Pre-stressed Concrete Institute (PCI) MNL 116, *Manual for Quality Control for Plants and Production of Structural Pre-cast Concrete Products*

- PCI MNL 117, *Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products*

- PCI MNL 120, *PCI Design Handbook: Pre-cast and Pre-stressed Concrete*

- PCI MNL 122, *Architectural Pre-cast Concrete*

- PCI MNL 135, *Tolerance Manual for Pre-cast and Pre-stressed Concrete Construction*

- Post-Tensioning Institute (PTI), *Post-Tensioning Manual*

- ASTM C1315-08, *Standard Specifications for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete*

- ASTM C938-02, *Standard Test Method for Congealing Point of Petroleum Waxes, Including Petrolatum*

- ASTM C150-07, *Standard Specification for Portland Cement*

- ASTM C317, *Standard Specification for Gypsum Concrete*

- ASTM C1107/C1107-08, *Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Non-shrink)*

- ASTM C143, *Standard Test Method for Slump of Hydraulic-Cement Concrete*

- ASTM C94, *User's Guide to ASTM Specification C94 for Ready-Mixed Concrete*

- National Roof Deck Contractors Association (NRDCA) 600, *Guideline for Application of Cementitious Wood Fiber Roof Deck Systems.*

5.2.2 Masonry Codes

Materials, design, and construction of masonry structures shall comply with:

- ACI 530-08/ASCE 5-08/The Masonry Society(TMS) 402-08, *Building Code Requirements for Masonry Structures*

- ASTM C1364, *Standard Specification for Architectural Cast Stone*

- ASTM C1194, *Standard Test Method for Compressive Strength of Architectural Cast Stone*

- ASTM C1195, *Standard Test Method for Absorption of Architectural Cast Stone*

- ASTM C173/C 173M-08a, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method*

- ASTM C231, REV C, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*

- ASTM C744, *Standard Specification for Pre-faced Concrete and Calcium Silicate Masonry Units*
- ASTM C1072, *Standard Test Method for Measurement of Masonry Flexural Bond Strength*
- ASTM E514, *Standard Test Method for Water Penetration and Leakage through Masonry*
- Local building codes, as applicable.

5.2.3 Steel and other Metal Codes

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

- American Institute of Steel Construction, Inc. (AISC) 303-05, *Code of Standard Practice for Steel Buildings and Bridges*
- AISC/American National Standards Institute (ANSI) 360-05, *Specification for Structural Steel Buildings*
- AISC/ANSI 341-05, *Seismic Provisions for Structural Steel Buildings*
- American Iron and Steel Institute (AISI)/COS/NASPEC 2001, *North American Specification for the Design of Cold-Formed Steel Structures*
- Steel Joist Institute (SJI), 2005 (42^{nd} edition), *Standard Specifications and Load Tables for Steel Joists and Joist Girders*
- Steel Deck Institute (SDI) 31, *Design Manual for Composite Decks, Form Decks, and Roof Decks*
- SDI DDMO3 (Third Edition), *Diaphragm Design Manual*
- American Welding Society (AWS) D1.1, *Structural Welding Code—Steel*
- AWS D1.3, *Structural Welding Code—Sheet Steel*
- AWS D1.4, *Structural Welding Code—Reinforced Steel*
- AWS A 5.3, *Specification for Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding*
- National Association of Architectural Metal Manufacturers (NAAMM), Metal Stairs Manual (AMP-510)
- NAAMM Metal Bar Gratings (ANSI/NAAM MBG 531)
- NAAMM Pipe Railing Manual (AMP 521)
- ASTM A47/47M, *Standard Specification for Ferritic Malleable Iron Castings*
- ASTM A27, *Standard Specification for Steel Castings, Carbon, for General Application*

- ASTM A153, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*
- ASTM C514, *Standard Specification for Nails for the Application of Gypsum Board*
- ASTM C636, *Standard Specification for Installation of Metal Ceiling Suspension Systems for Acoutiscal Tile and Lay-in Panels*
- ASTM B221M, *Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes*
- ASTM B209M, *Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate*
- ASTM B26M-05*, Standard Specification for Aluminum-Alloy Sand Castings*
- ASTM B247, *Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings*
- American Society of Mechanical Engineers (ASME) B18.3.3, *Hexagon Socket Head Shoulder Screws*
- ASME B18.2.1, *Square and Hex Bolts and Screws*
- ASME B18.2.4, *Metric Hex Nuts, Style I*
- ASME B18.2.2, *Square and Hex Nuts*
- ASME B18.2.3, *Metric Hex Cap Screws*
- ASME B18.6.7, *Metric Machine Screws*
- ASME B18.6.3, *Machine Screws and Machine Screw Nuts*
- ASME B18.6.5, *Metric Thread-Forming and Thread-Cutting Tapping Screws*
- ASME B18.6.1, *Wood Screws*
- ASME B18.22, *Plain Washers*
- ASME B18.21, *Lock Washers*
- ASME B18.13, *Screw and Washer Assemblies*
- SSPC PS 11.01, *Black (or Dark Red) Coal Tar Epoxy Polyamide Painting System*
- Local building codes, as applicable.

5.2.4 Pre-Engineered Building Codes

Pre-engineered metal buildings shall comply with:

- The Metal Building Manufacturers Association (MBMA), *Metal Building Systems Manual*
- Local building code, as applicable.

5.2.5 Additional Building Codes

The following additional building codes or more recent versions may apply:

- American Forest and Paper Association (AF&PA) NDS 2001, *National Design Specification for Wood Construction and 2005 Supplement*
- ASCE 7-05, *Minimum Design Loads for Buildings and Other Structures*
- ASCE 37-02, *Design Loads on Structures During Construction*
- American Association of State Highway & Transportation Officials (AASHTO), Load and Resistance Factor Design (LRFD), Bridge Design Specifications
- International Code Council, International Building Code
- AISC 327-05, *Seismic Design Manual*.

5.3 Concrete

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

5.3.1 Forms

Formwork for concrete construction shall comply with ACI 117, ACI 347R, ACI SP-4, and state building codes, as applicable.

5.3.1.1 Form Construction

Forms shall be constructed true to the structural design and required alignment. The form surface and joints shall be mortar-tight and supported to achieve safe performance during construction, concrete placement, and form removal. The alignment and stability of the forms shall be continuously monitored during all phases to assure the finished product will meet the required surface class. When forms for continuous surfaces are placed in successive units, care shall be taken to fit the forms over the completed surface to obtain accurate alignment of the surface and to prevent leakage of mortar. Forms shall not be reused if there is any evidence of defects that would impair the quality of the resulting concrete surface. All surfaces of used forms shall be cleaned of mortar and any other foreign material before reuse.

5.3.1.2 Chamfering

All exposed joints, edges, and external corners shall be chamfered by molding placed in the forms, unless the drawings specifically state that chamfering is to be omitted or as otherwise specified. Chamfered joints shall not be permitted where earth or rockfill is placed in contact with concrete surfaces. Chamfered joints shall be terminated 12 inches outside the limit of the earth or rockfill so that the end of the chamfers will be clearly visible.

5.3.1.3 Coating

Forms for exposed or painted surfaces shall be coated with form oil or a form-release agent before the form or reinforcement is placed in final position. The coating shall be used as recommended in the manufacturer's instructions. Forms for unexposed surfaces may be wet with water in lieu of coating immediately before placing concrete, except that in cold weather, when freezing temperatures are anticipated, coating shall be mandatory. Surplus coating on form surfaces and coating on reinforcing steel and construction joints shall be removed before emplacing concrete.

5.3.1.4 Form Removal

Forms shall not be removed without approval. The minimal time required for concrete to reach a strength adequate for removal of formwork without risking the safety of workers or the quality of the concrete depends on a number of factors including, but not limited to:

- Ambient temperature
- Concrete lift heights
- Type and amount of concrete admixture
- Type and amount of cementitious material in the concrete.

Forms shall not be removed until these criteria are attained.

Where forms support more than one element, the forms shall not be removed until the form removal criteria are met by all supported elements. Evidence that concrete has gained sufficient strength to permit removal of forms shall be determined by tests on control cylinders. All control cylinders shall be stored in the structure or as near the structure as possible, such that they receive the same curing conditions and protection methods as given those portions of the structure they represent. Control cylinders shall be removed from the molds at an age of no more than 24 hours. All control cylinders shall be prepared and tested in accordance with ASTM C31/C31M and ASTM C39/C39M. Use of maturity instrumentation instead of control cylinders to determine the compressive strength of the concrete must be pre-approved by EPA. ASTM C1074 procedures shall be used for estimating concrete strength by means of the maturity method.

5.3.2 Reinforcement

Reinforcement materials (e.g., metal reinforcing bars, glass fiber, plastic fiber) for buildings and other incidental structures shall comply with state building codes and ACI 318-08, as applicable. Reinforcement details shall comply with ACI SP-66-04, ACI 318-08, and state building codes, as applicable.

5.3.2.1 Dowels

Dowels shall conform to ASTM A675/A675M, Grade 80. Steel pipe conforming to ASTM A53/53M, Schedule 80 may be used as dowels provided the ends are closed with metal or plastic inserts or with mortar.

5.3.2.2 Fabricated Bar Mats

Fabricated bar mats shall conform to ASTM A184/184M.

5.3.2.3 Reinforcing Steel

Reinforcing steel shall be deformed bars conforming to ASTM A615/A615M or ASTM A706/A706M, grades and sizes as indicated. Cold drawn wire used for spiral reinforcement shall conform to ASTM A82/A82M. In highly corrosive environments or when directed by the Project Structural Engineer, reinforcing steel shall conform to ASTM A767/A767M or ASTM A775/A775M, as appropriate.

5.3.2.4 Welded Wire Fabric

Welded wire fabric shall conform with ASTM A185/A185M, ASTM A496/A496M, or ASTM A497/A497M, as applicable. When directed by the Project Structural Engineer for special applications, welded wire fabric shall conform to ASTM A884/A884M.

5.3.2.5 Wire Ties

Wire ties shall be 16 gauge or heavier, black, annealed steel wire.

5.3.2.6 Supports

Bar supports for formed surfaces shall be designed and fabricated in accordance with Concrete Reinforcing and Steel Institute (CRSI) 10MSP and shall be steel or pre-cast concrete blocks. Pre-cast concrete blocks shall have wire ties and shall be not less than four inches square when supporting reinforcement on ground. Pre-cast concrete block shall have compressive strength equal to that of the surrounding concrete. Where concrete-formed surfaces will be exposed to weather or where surfaces are to be painted, steel supports within ½ inch of the concrete surface shall be galvanized, plastic protected, or fabricated from stainless steel. Concrete supports used in concrete exposed to view shall have the same color and texture as the finish surface. For slabs-on-grade, supports shall be pre-cast concrete blocks, plastic-coated steel fabricated with bearing plates, or specifically designed wire-fabric supports fabricated from plastic.

5.3.2.7 Synthetic Fiber Reinforcement

Synthetic fiber shall be polypropylene with a Denier value less than 100 and a nominal fiber length of two inches.

5.3.3 Cast-in-Place Concrete

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

5.3.3.1 Materials, Testing, and QA/QC

Materials, testing, and QA/QC shall comply with ACI 318-08, ACI 301-05, 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.

5.3.3.2 Tolerances

Tolerances shall be as recommended in ACI 347R, ACI 117-06, and state building code.

5.3.3.3 Selecting Proportions for Concrete Mixes

The proportions for concrete mixes of normal-weight concrete shall comply with state building code and ACI 318 and 211.1. The proportions for structural lightweight concrete shall comply with state building code and ACI 318 and 211.2. The following minimum cement factors in Table 5-1 shall be achieved for all applications:

Table 5-1: Minimum Cement Factors

Concrete Strength		Non Air-Entrained	Air-Entrained	
Minimum 28-Day Compressive Strength (psi)	Minimum Cement (lbs/yd^3)	Maximum Water/Cement Ratio	Minimum Cement (lbs/yd^3)	Maximum Water/Cement Ratio
5,000[1,3]	630	0.45	650	0.40
4,000[1,3]	550	0.55	570	0.50
3,000[1,3]	470	0.65	490	0.55
3,000[1,2]	500	*	520	*

1. If trial mixes are used, the proposed mix design shall achieve a compressive strength of 1,200 psi in excess of the minimum compressive strength (f'c) listed herein.
2. Lightweight structural concrete. Pump mixes may require higher cement values.
3. For concrete exposed to high sulfate content soils, the maximum water/cement ratio is 0.44.

* Determined by an approved laboratory in according with ACI 211.1 for normal concrete or ACI 211.2 for lightweight structural concrete.

PSI – pounds per square inch

5.3.3.4 Mixing, Transporting, and Placing

Mixing, transporting, and placing shall comply with the recommendations of state building code and ACI 304R. If trial mixes are used, the proposed mix design shall achieve a compressive strength 1,200 psi in excess of the compressive strength (f'c). For concrete strengths above 5,000 psi, the proposed mix design shall achieve a comprehensive strength 1,400 psi in excess of the f'c.

Cement should be delivered in original sealed containers bearing names of the brand and manufacturer, and marked with net weight of the contents. Cement should be stored in a suitable watertight building, in which the floor is raised at least one foot above the ground surface.

Maximum slump values for concrete to be vibrated (as determined by ASTM C143, with tolerances as established by ASTM C94) are presented in Table 5-2:

Table 5-2: Maximum Slump (Inches) for Different Concrete Formulations*

Type of Construction	Normal Weight Concrete	Lightweight Structural Concrete
Reinforced Footings and Substructure Walls	3 inches	3 inches
Slabs, Beams, Reinforced Walls, and Building Columns	4 inches	4 inches

* Slump may be increased by the use of approved, high-range, water-reducing admixtures (superplasticizers). Tolerances are as established by ASTM C94.

5.3.3.5 Climatic Considerations

Hot-weather concreting shall comply with the recommendations of state building code and ACI 305R, to prevent problems in manufacturing, placing, and curing of concrete that can adversely affect the properties and serviceability of the hardened concrete. Cold-weather concreting shall comply with the recommendations of state building code and ACI 306R, to prevent freezing of concrete and to enable the concrete to gain strength quickly. Set accelerators shall not be allowed except when specific approval is given by the project structural engineer and EPA project manager. Only the specified non-corrosive, non-chloride accelerator(s) shall be used on the project.

5.3.4 Pre-cast/Pre-stressed/Post-tensioned Concrete

5.3.4.1 Structural

In addition to meeting the requirements of other subsections, pre-cast and pre-stressed concrete structures shall comply with PCI Manual (MNL) 116. PCI MNL-120 and PCI-MNL-135 may also be used as a guide for the design and construction of pre-cast concrete structures.

Concrete mixes should be either the following or what is called for in code (whichever is more stringent):

- <u>Normal-Weight Concrete</u>
  Compressive Strength: 5,000 pounds per square inch (psi), minimum at 28 days
  Release Strength: 3,500 psi, minimum at transfer of pre-stress
- <u>Lightweight Concrete</u>
  Compressive Strength: 5,000 psi, minimum at 28 days
  Release Strength: 3,500 psi, minimum at transfer of pre-stress
  Air-Dry Density: Not less than 90 pounds per cubic foot (pcf), nor more than 115 pcf
  Drying Shrinkage: Maximum 0.035 percent at 28 days

In additional, concrete should not contain calcium chloride, chloride ions, or other salts.

5.3.4.2 Architectural

In addition to meeting the requirements of other subsections, architectural pre-cast members shall comply with the PCI MNL-117, 120 and 122.

5.3.4.3 Post-tensioned Concrete

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

5.3.4.4 Concrete Grouting

In addition to the standards and resources referenced in other concrete and pre-cast concrete subsections, ASTM C938-02 (or latest version) may also be used for the pre-cast and post-tensioned concrete structures. Sand-cement grout should comply with ASTM C150 and generally should be mixed at ratio of one part cement to 2.5 parts sand, by volume, with minimum water required for placement and hydration. Non-metallic, non-shrink grout should comply with ASTM C1107.

5.3.5 Cementitious Decks

All cementitious deck materials should comply with ASTM C150 and C317, as well as the other requirements listed herein.

Bulb tees should be spaced accurately according to specifications (plus or minus 1/16 inch) and securely positioned by means of templates. The tees should be welded at every point of crossing over the main framing members by means of fillet welds on alternate sides of the tee flanges, at intermediate supports for spans of less than eight feet (both sides on spans longer than eight feet), and on both sides of the tees at the ends. Fillet welds should be a minimum of ¾ inch in length.

Expansion joints may be included only as approved by the Project Structural Engineer. The attachment must meet the uplift requirements of the local building code. When laying tees on a wood purlin, welding plates spaced at 24 inches or 32 inches on center shall be nailed or screwed to the purlin, and the tees then welded to the plates. Where concrete purlin(s) are used, steel inserts should be installed.

Cementitious deck tile should be spaced evenly between the bulb tees to provide a minimum edge bearing of ½ inch. When laying tile, all joints running perpendicular to the bulb tees shall be broken by starting with a full tile, then a half tile, in alternating rows. When square-end, special length tile is applied, the ends should fall over the bulb tee supports. Tile lengths should be staggered, where practical. On sloped decks, when tees are placed parallel with the ridge, the tile spacing must be carefully checked, since the cementitious deck will naturally bear more on the lower bulb tee.

Ensure that planks are installed and anchored properly. Any welding should comply with AWS D1.1.

5.3.5.1 Gypsum Concrete Roof/Floor Decks

Gypsum concrete roof/floor decks should, where possible, be consistent with the following:

- Deck planks should be normal size, two inches thick by 24 inches wide by the main purlin span. Where possible, the total length should extend over two main purlin spans.
- Deck panels should be 16 mm (⅝ inch) thick by 600 mm (24 inches) wide by main purlin span.
- Sub-purlins should be spaced at approximately 650 mm (24⅝ inches) on center to provide minimum 16 mm (⅝ inch) continuous bearing for gypsum plank or deck.

5.3.6 Curing

It is critical that care is taken to properly cure concrete in order to achieve the optimal strength and hardness and reduce evaporation. The content of the mixture, external temperature, relative humidity, and all other relevant factors must comply with ACI 318-08 and local building codes. For additional guidance on curing processes and testing, refer to ASTM 1315-08.

5.3.7 Specialty Concretes

Specialty concretes include white and colored concrete, often used for architectural and decorative purposes. In addition to meeting all other concrete requirements, specialty concretes should conform to the following codes and standards:

- White cement should conform to ASTM C150 (Types I through V are all covered).
- Blended cement should conform to ASTM C595, includes other pozzolanic or slag materials in the cement.

- Hydraulic cement should conform to ASTM C1157. Six types of cement are closely correlated with ASTM C150.

Refer to Tables 5-3 and 5-4 below for further descriptions of types of specialty concrete and how they are used:

Table 5-3: Applications of Commonly Used Cements

Cement Specification*	Applications**			
	General Purpose	Moderate Heat of Hydration	High Early Strength	Low Heat of Hydration
ASTM C150 (AASHTO M85) Portland Cements	I	II	IV	II
ASTM C595 (AASHTO M240) Blended Hydraulic Cements	IS IP	IS (<70)(MH) IP (MH)	NA	IP (LH)
ASTM C1157 Hydraulic Cements***	GU	MH	HE	LH

* The option for low reactivity with alkali-silica reactivity (ASR)-susceptible aggregates can be applied to any cement type in this table.

** Check the availability of specific cements, as all cements are not available everywhere.

*** For ASTM C1157 cements, the nomenclature of hydraulic cement, Portland cement, air-entraining Portland cement, modified Portland cement, or blended hydraulic cement is used with the type designation.

Source: Portland Cement Association, http://www.cement.org/decorative/index.asp

Table 5-4: Applications of Commonly Used Cements (cont.)

Cement Specification*	Applications**		
	Moderate Sulfate Resistance	High Sulfate Resistance	Resistance to ASR
ASTM C150 (AASHTO M85) Portland Cements	II	V	Low-alkali option
ASTM C595 (AASHTO M240) Blended Hydraulic Cements	IS (<70)(MS) IP (MS)	IS (<70)(HS) IP (HS)	Low-reactivity option
ASTM C1157 Hydraulic Cements***	JS	HS	Option R

* The option for low reactivity with alkali-silica reactivity (ASR)-susceptible aggregates can be applied to any cement type in this table.

** Check the availability of specific cements, as all cements are not available everywhere.

*** For ASTM C1157 cements, the nomenclature of hydraulic cement, Portland cement, air-entraining Portland cement, modified Portland cement, or blended hydraulic cement is used with the type designation.

Source: Portland Cement Association, http://www.cement.org/decorative/index.asp

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5.3.8 Construction Inspection and Testing

Inspection and testing shall comply with the requirements of the state building code and ACI 318-08, and where additionally specified in this chapter.

5.3.9 Repair and Restoration of Concrete Structures

Methods, procedures, and materials for the repair and restoration of concrete structures shall comply with applicable state building codes and guidelines ACI 503.4 and ACI 546.1R.

5.3.10 Fly Ash and Other Recovered Mineral Additives

Use of coal fly ash and other pozzolanic materials as an admixture in concrete is discussed in Section 4.5.2 of this Manual.

5.4 Masonry

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.

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 source shall also be used as guides for the design of masonry structures: ACI 530-08/ASCE 5-08/TMS 402-08.

5.4.1 Unit Masonry

Materials, design, and construction of masonry units shall be in accordance with the requirements in Section 5.2, *Relevant Codes and Standards*, and the following:

- Solid Clay or Shale Brick - ASTM C62, *Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale*

- Hollow Clay or Shale Brick - ASTM C652, *Standard Specification for Hollow Brick (Hollow Masonry Units Made from Clay or Shale*

- Concrete Brick - ASTM C55, *Standard Specification for Concrete Brick*

- Hollow and solid concrete masonry units - ASTM C90, *Standard Specification for Load-bearing CMUs*

- Pre-faced concrete masonry units - ASTM C744, using masonry units conforming to ASTM C90

- Ceramic glazed structural clay facing units - ASTM C126, *Standard Specification for Ceramic-Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units.*

5.4.1.1 Anchoring

When anchoring masonry in the following situations, consider:

- Veneer to frame walls – Use adjustable veneer anchors and space anchors not more than 16 inches on center vertically at each stud

- Veneer to concrete walls – Anchor new masonry facing to existing concrete with corrugated wall ties spaced at 16-inch maximum vertical intervals, and at two-foot maximum horizontal intervals. Fasten ties to concrete with power-actuated fasteners or concrete nails

- Masonry facing to backup and cavity wall ties – Stagger ties in alternate courses, and space at 16 inches maximum vertically, and two feet horizontally. At openings, provide additional ties spaced not more than three feet apart vertically around perimeter of the opening, and within 12 inches from edge of the opening. Anchor new masonry facing to existing masonry with corrugated wall ties spaced at 16 inch maximum vertical intervals and at every second masonry unit horizontally. Fasten ties to masonry with masonry nails

- Anchorage on abutting masonry – Anchor interior four-inch thick masonry partitions to exterior masonry walls with wall ties. Space ties at two-foot maximum vertical intervals. Extend ties four inches (minimum) into masonry

- Masonry furring – Anchor masonry furring less than four inches nominal thickness to masonry walls or to concrete with corrugated wall ties or dovetail anchors

- Anchorage to steel beams or columns – Use adjustable beam anchors on each flange. At columns, weld the ¼-inch steel rod to steel columns at 12 inch intervals, and place wire ties in masonry courses at 16 inches (maximum) vertically.

5.4.1.2 Tooling Joints

Finish joints in exterior face masonry work with a jointing tool, and provide smooth, water-tight concave joints unless specified otherwise. Other joint types as specified by the project architect may also be used. Tool exposed interior joints in finish work concave unless otherwise specified. Do not tool until mortar has stiffened enough to retain a thumb print when thumb is pressed against mortar. Tool while mortar is soft enough to be compressed into joints and not raked out.

5.4.1.3 Partition Height

Partitions should be extended at least four inches above suspended ceilings, or to overhead construction where no ceiling occurs. Interior masonry partitions used for required fire separation shall extend to underside of deck above and be completely sealed at that point.

5.4.1.4 Lintels

Lintels are not required for openings less than 40 inches wide that have hollow metal frames. Openings 41 inches wide to 64 inches wide, with no structural steel lintel or frames, require a lintel formed of concrete masonry lintel, bond beam units, or structural facing tile lintel units filled with grout per ASTM C476 and reinforced with one No. 15 (one No. 5) rod top and bottom for each four inches of nominal thickness, unless indicated otherwise on project plans. Pre-cast lintels of 3,000 psi concrete, of same thickness as the partition, and with one No. 5 deformed bar top and bottom for each four inches of nominal thickness, may be used in lieu of reinforced CMU masonry lintels. Use steel lintels for openings over 64 inches wide in brick and masonry, and across elevator openings, unless shown otherwise. Masonry openings or arches should be built over wood or metal centering when steel lintels are not used.

5.4.1.5 Walls, Furring, and Partition Units

Lay out field units to provide for running bond of walls and partitions, with vertical joints in second course centering on first course units (unless specified otherwise). Running, English, Flemish or variations of each bond types, as specified by the project architect, shall be used. Align head joints of alternate vertical courses, balancing at sides of the openings and on vertical center lines. Use no piece shorter than four inches long. On interior partitions, provide a ¼-inch open joint for caulking between existing construction, exterior walls, concrete work, and abutting masonry partitions. Use not less than four inches nominal thickness masonry for freestanding furring (unless specified otherwise). Do not abut existing plastered surfaces, except suspended ceilings with new masonry partitions.

5.4.1.6 Chases

Do not install chases in masonry walls and partitions exposed to view in finished work, including painted or coated finishes on masonry. Masonry that is four-inch nominal thickness may have electrical conduits one inch or less in diameter, when covered with soaps or other finishes. When pipes or conduits (or both) occur in hollow masonry unit partitions, retain at least one web of the hollow masonry units.

5.4.1.7 Formwork

Provide formwork and shores as required for temporary support of reinforced masonry elements. Construct formwork to conform to shape, line, and dimensions needed. Make sufficiently tight to prevent leakage of mortar, grout, or concrete (if any). Brace, tie, and support as required to maintain position and shape during construction and curing of reinforced masonry. Do not remove forms and shores until reinforced masonry members have hardened sufficiently to carry their own weight and all other reasonable temporary loads that may be placed on them during construction.

5.4.1.8 Additional Masonry Guidance

General installation guidance for unit masonry:

- Keep finish work free from mortar smears or spatters, and leave neat and clean

- Fill hollow metal frames built into masonry walls and partitions with solid mortar as laying of masonry progresses. If items are not available when walls are built, prepare openings for subsequent installation

- Do not use less than four-inch nominal thickness masonry for fireproofing steel columns unless specified otherwise

- Before connecting new masonry with previously laid substrate, remove loosened masonry or mortar, and clean and wet work in place

- Do not lay wet concrete masonry units or glazed structural facing tile before laying masonry

- When structural steel is encased in masonry, the voids between steel and masonry should be filled with mortar, allowing a minimum of one inch free expansion space. Do not place spacing material where steel is bearing on masonry or masonry is bearing on steel

- Allow not less than the following minimum time to elapse after completion of members before removing shores or forms, provided suitable curing conditions have been obtained during the curing period:

    - 10 days for girders and beams

    - 7 days for slabs

    - 7 days for reinforced masonry soffits

- Provide a masonry sample panel constructed on site to be used as a guide for acceptable masonry materials and joint work. The panel should not be demolished until permission is given by the project architect and EPA project manager.

5.4.1.9 Grout

Any grout used must conform with ASTM C476. Grout compressive strength should be at least 2,000 psi at 28 days. Fine grout should be used for filling wall cavities and cells of CMUs where the smallest dimension is two inches or less. Either fine grout or coarse grout should be used for filling wall cavities and cells of CMUs where the smallest dimension is greater than two inches. Grout should not be used for filling bond beam or lintel units.

5.4.2 Stone Assemblies

Stone for trim, sills, lintels, and copings shall be limestone, sandstone, or granite. Sandstone shall be standard grade, buff, gray, or buff brown, with a smooth finish free from clay pits and tool marks. Granite shall be a good quality, commercial-grade building granite: (1) of medium or moderately coarse grain; (2) a light or medium gray or light pink color; (3) with a smooth machine finish on washes; (4) four-cut finish on treads; and (5) six-cut or equivalent machine finish on other exposed surfaces. Limestone shall be standard buff limestone, with a smooth machine finish free from tool marks. Stone shall be properly anchored to supporting structures in accordance with ASTM C1242.

Lintels, except when supported by a steel member, shall be four inches or more in thickness from face to back edge and of the depth required to support the masonry over the opening. Stone shall have beds and joints at right angles to the face, with sharp, true arises. Copings and sills shall be provided with washes, and where overhanging the walls, shall have drips cut on the underside.

5.4.2.1 Architectural Cast Stone

Architectural cast stone should comply with ASTM D1364. Physical properties should be as follows:

- Compressive Strength – ASTM C1194; 6,500 psi minimum for products at 28 days
- Absorption – ASTM C1195; six percent maximum by the cold water method, or 10 percent maximum by the boiling method for products at 28 days.
- Air Content – ASTM C173 or C231; for wet cast product shall be four percent to eight percent for units exposed to freeze-thaw environments. Air entrainment is not required for vibrant dry tamp (VDT) products.
- Freeze/Thaw – ASTM C1364L; the cumulative percent weight loss shall be less than five percent after 300 cycles of freezing and thawing.
- Linear Shrinkage – ASTM C426L; shrinkage shall not exceed 0.065 percent.

Color and finish should match sample(s) on file, with surfaces exposed to view having a fine-grained texture similar to natural stone and with no air voids larger than 1/32 inch. The density of such voids shall be fewer than three occurrences per one inch squared and not obvious under direct daylight illumination at a distance of five feet. Stone should be selected and installed in conformance with ASTM D2244, allowing permissible variation in color between units of comparable age subjected to similar weathering exposure:

- Total Color Difference – Not greater than six units
- Total Hue Difference – Not greater than two units.

5.4.2.2 Reinforcing

Units should be reinforced as required by drawings and for safe handling and structural stress; minimum reinforcing shall be 0.25 percent of the cross-sectional area. Reinforcement shall be non-corrosive where faces exposed to weather are covered with less than 1.5 inches of concrete material. All reinforcement shall have minimum coverage of twice the diameter of the bars.

5.4.3 Corrosion-Resistant Masonry

The design shall minimize damage to masonry from water filtration by using water-repellant admixture for masonry units and mortar on single-wythe, CMU exterior walls. Panels of masonry units conforming to ASTM C744 and mortar that contain water-repellant admixture should be tested in accordance with ASTM C1072, and have flexural strength not less than that specified or indicated by the Project Architect or Structural Engineer. When tested in accordance with ASTM E514, panels shall exhibit no water visible on back of test panel and no leaks through the panel after 24 hours, and not more than 25 percent of the wall area shall be damp after 72 hours.

5.4.3.1 Weep Holes

Weep holes and damp-proofing should be included in geographic areas where they are acceptable and necessary practices. Wherever through-wall flashing occurs, provide weep holes to drain flashing to the exterior at acceptable locations as indicated on the project plans. Weep holes shall be full-open head joints, 20 inches on center for brick-faced walls and minimum two-inch, open-head joints 32 inches on center for CMU construction. Weep holes shall be provided not more than 24 inches on center in mortar joints of the exterior wythe above the wall flashing, over foundations, bond beams, and any other horizontal interruptions of the cavity.

Weep holes shall be plumb and level to the horizontal or slightly canted downward to encourage water drainage outward and preclude drainage inward. Weep holes shall be formed by placing short lengths of well-greased No. 10, 5/16-inch nominal diameter, braided cotton sash cord in the mortar and withdrawing the cords after the wall has been completed. Weep holes shall be constructed using weep hole ventilators. Weep holes shall be kept free of mortar and other obstructions.

Weep hole ventilators shall be pre-fabricated aluminum, plastic, or wood blocking sized to form the proper size opening in the head joints. Provide aluminum and plastic inserts with grill- or screen-type openings designed to allow the passage of moisture from cavities and to prevent the entrance of insects. Ventilators shall be sized to match modular construction with a standard ⅜-inch mortar joint.

5.4.4 Masonry Inspection and Testing

Inspection and testing of unit masonry, grout, mortar reinforcing, and accessories shall comply with ACI 530.1-08 and state/local building code, as applicable. When the masonry compressive strength used in the design is greater than 1,500 psi, a qualified independent masonry inspector approved by the EPA Project Manager shall perform inspection of the masonry work. Minimum qualifications for the masonry inspector shall be five 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 the contractor complies with all drawings and specifications. The masonry inspector shall keep a complete record of all inspections and shall submit daily written reports to the EPA Project Manager or QA Officer reporting the quality of masonry construction.

5.5 Steel and Other Metals

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 as permitted by code.

5.5.1 Structural Framing

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.

5.5.2 Joists

5.5.2.1 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*.

5.5.2.2 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.

5.5.2.3 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.

5.5.3 Decking

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.*

5.5.4 Fabrications

All steel and other metal fabrications must meet the requirements of AISC Code of Standard Practice. All steel fabricators must be certified Steel Building Structure Fabricators, in accordance with AISC requirements (AISC, *Certification Standard for Steel Building Structures*).

5.5.5 Stairs and Railings

In addition to conforming to the other standards for metal fabrication, stairs should be designed to support a live load of at least 100 pounds per square foot. Structural design, fabrication, and assembly of stairs and railings should be in accordance with requirements of National Association of Architectural Metal Manufacturers (NAAMM), *Metal Stairs Manual*, except as otherwise specified. Grating treads should be designed in accordance with the NAAMM *Metal Bar Grating Manual*.

The location of stairs within buildings should encourage their use, in lieu of elevators, to the fullest extent feasible. This will reinforce the recognition of sustainable energy conservation.

5.5.5.1 Railings

Metal pipe railings should be designed in accordance with NAAMM *Pipe Railing Manual* for 200 pounds force in any direction and at any point.

5.5.6 Ladders and Rungs

In addition to conforming to the other standards for metal fabrications, ladders should be designed to support a live load of at least 250 pounds force at any point.

In elevator pits, ensure ladders clear all elevator equipment where shown on the project plans; where ladders are interrupted by division beams, anchor ladders to the beams by welding, and to floors with expansion bolts. Where ladders are adjacent to division beams, anchor ladders to the beams with bent steel plates, and to the concrete floor with expansion bolts.

5.5.7 Fire Escapes

The project shall follow the standards set forth in NFPA 101. EPA will not permit the use of fire escape stairs for new construction. New fire escape stairs shall be permitted to be constructed on existing building only where the EPA has determined that outside stairs are impractical. The fire escape stairs shall not incorporate ladders or access windows, regardless of occupancy classification or occupant load served.

Non-combustible materials shall be used for the construction of all components of fire escape stairs. Stair treads and landings of new or replacement fire escape stairs shall have slip-resistant surfaces. All fire escape stairs shall have walls or guards and handrails on both sides. Replacement fire escape stairs in occupancies serving more than 10 occupants shall have visual enclosures to avoid any impediments to stair use by persons suffering from acrophobia (i.e., fear of heights).

Fire escape stairs shall be exposed to the smallest possible number of window and door openings, and each opening shall be protected in accordance with NFPA 101. Where access is permitted by way of windows, the windows shall be arranged and maintained such that they can be easily opened. Screening or storm windows that restrict free access to the fire escape stair are prohibited. Fire escape stairs shall extend to the roof in all cases where the roof is subject to occupancy or provides an area of safe refuge, unless otherwise specified in NFPA 101. Access to the fire escape stair shall be directly to a balcony, landing, or platform; shall not exceed the floor or windowsill level; and shall not be more than eight inches below the floor level or 18 inches below the window sill level.

5.5.8 Metal Specialties

Metal specialties cover metal products used in building construction for architectural and decorative effects. Several common examples that may be used on EPA projects are described below:

5.5.8.1 Concrete Inserts

Concrete inserts must be used for fastening ornamental metal items to cast-in-place concrete construction when the anchorage device will be subjected to direct pull-out loadings (e.g., fascia flanges for ornamental features). Inserts must be galvanized, box-type, ferrous castings with integral anchor loop at back of the box and be designed to accept bolts having special wedge-shaped heads. Ferrous castings must be malleable iron conforming to ASTM A47/A47M, Grade 32510 or Grade 35018, Grade 22010 or Grade 24118, or medium-strength cast steel conforming to ASTM A27/A27M, Grade U-60-30. Inserts must be hot-dip galvanized after fabrication, in accordance with ASTM A153/A153M.

Carbon steel bolts must be provided with special wedge-shaped heads, nuts, washers, and shims, and must be hot-dip galvanized in accordance with ASTM A153/A153M. Concrete inserts must be non-removable when embedded in concrete of 3,000 psi compressive strength and subjected to a 6,000 pound tension load test in an axial direction. Concrete must not indicate any evidence of failure attributable to the anchoring device itself.

5.5.8.2 Masonry Anchorage Devices

Masonry anchorage devices may be used only for the fastening of ornamental metal items to solid masonry and cast-in-place concrete construction, when the anchorage device will not be subjected to direct pull-out loadings or to vibration. Masonry anchorage devices must be used only for non-vibratory shear loads. Masonry anchorage devices must be expansion shields conforming to ASTM C514.

5.5.8.3 Toggle Bolts

Toggle bolts must be used for fastening ornamental metal items to hollow masonry and stud partitions. Provide toggle bolts of the class and style best suited for the work, conforming to ASTM C636/C636M, Type II. Toggle bolts must be corrosion-resistant, chromium-nickel steel conforming to American Iron and Steel Institute (AISI) Type 302, 303, 304, 305, or 316.

5.5.8.4 General Workmanship

Metalwork must be well formed to shape and size, with lines, angles, and curves true. Fasteners shall be concealed where practical. Exterior ornamental metal items shall be designed to withstand expansion and contraction of the component parts at an ambient temperature of 100 degrees Fahrenheit (°F) without causing harmful buckling, opening of joints, overstressing of fasteners, or other harmful effects.

Welded fabrication must meet the requirements specified in AWS D1.2/D1.2M. Welded joints must be cleaned of flux and dressed on exposed and contact surfaces. Corner joints must be coped or mitered, well-formed, and in true alignment. Joints exposed to weather must be formed and fabricated to exclude water. Castings must be sound and free from warp or defects that impair their strength and appearance.

5.6 Pre-Engineered Structures

All pre-engineered structures discussed in this Manual are commercially-designed structures, fabricated by industry to conform to the local design specifications and applicable codes. The advantage of pre-engineered structures is that they are factory-built and designed to be erected in the shortest possible time. The key disadvantages are appearance and potential inconsistency with the required application. Each pre-engineered structure is shipped as a complete kit including all the necessary materials and instructions to erect it. Rigid-frame buildings, K-spans, steel towers, and antennas are some of the more commonly used structures.

5.6.1 Minimum Specifications

All pre-engineered structures will conform to the appropriate local design specifications and applicable codes.

6. MECHANICAL REQUIREMENTS

6.1 Relevant Codes, Standards, and Regulations

The mechanical design engineer shall be responsible for ensuring that all mechanical systems conform to the requirements of this section, and that all systems are installed in accordance with:

- All governing codes, ordinances, and regulations
- The most recent edition of applicable technical publications; and
- Other requirements, as set forth below.

The design engineer is responsible for the design of all mechanical systems and components, including mains, lines, meters, and other equipment 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 the U.S. Environmental Protection Agency's (EPA) energy conservation and environmental protection goals, including minimization of air pollution, water pollution, and waste generation/disposal.

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 EPA's Architecture, Engineering, and Asset Management Branch (AEAMB); Sustainable Facilities Practices Branch (SFPB); and Safety, Health, and Environmental Management Division (SHEMD), all mechanical system installations shall conform to the standards listed below:

- National Fire Protection Association (NFPA) 31
- NFPA 37
- NFPA 45
- NFPA 54
- NFPA 58
- NFPA 59A
- NFPA 90A
- NFPA 91
- NFPA 92A
- NFPA 96
- NFPA 214
- American National Standards Institute (ANSI) A17.1
- ANSI Z358.1

LEED-NC 2009 strongly encourages facilities to maximize their energy performance. EPA facilities that comply with the EO 13423-required 30 percent improvement over ASHRAE 90.1-2007 can receive at least 10 points (and as many as 19 points), depending on the level of energy savings compared to a specified baseline value. Numerous strategies and technologies covered in this section aid in improving energy performance/reducing total energy consumption. (*Energy use reduction beyond 48 percent in new buildings or 44 percent in major renovations of existing buildings may also present an opportunity to earn Innovation in Design points; check the LEED Reference Guide for instructions*).

- ANSI/American Industrial Hygiene Association (AIHA) Z9.2
- U.S. Department of Health and Human Services (HHS)/National Institute for Occupational Safety and Health (NIOSH) Publication 2002-139, *Protecting Building Environment from Airborne Chemical, Biological, or Radiological Attacks*
- EPA SHEMD, *Draft Performance Requirements for Laboratory Fume Hoods*
- EPA: *Building Air Quality: A Guide for Building Owners and Facility Managers*, EPA/400/1-91/033
- American Conference of Governmental Industrial Hygienists (ACGIH), *Industrial Ventilation: A Manual of Recommended Practice*
- National Research Council, *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*
- National Sanitation Foundation (NSF) Standard 49
- NSF Standard 61
- ANSI/AIHAZ9.5
- ANSI/American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) 15
- Energy Policy Act of 2005 (EPAct 2005), Subtitle A, *Energy Efficiency – Federal Programs*
- Energy Independence and Security Act of 2007 (EISA 2007), Title IV, Subtitle C, *High Performance Federal Buildings* and Title V, Subtitle C, *Energy Efficiency in Federal Agencies*
- Executive Order (EO) 13423
- EO 13514
- *Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding* (Federal Sustainable Buildings MOU)
- International Building Code (IBC)
- International Mechanical Code
- International Plumbing Code (IPC).

Additional specifications are detailed in the body of this chapter, at the time they are referenced.

6.2 Heating, Ventilation, and Air Conditioning (HVAC) Design Criteria

Building HVAC systems and subsystems shall be evaluated, and major HVAC equipment components shall be selected, taking into consideration health and safety requirements, occupant comfort, attributed atmospheric emissions of regulated air pollutants, first (capital) costs, operation and maintenance (O&M) costs, and life cycle costs. A life cycle cost analysis (LCCA) shall be performed using 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. Refer to Chapter 1 of this Manual for additional information on conducting LCCAs. Section 104 of EPAct 2005 also requires that, when procuring energy-consuming products, all Federal agencies procure either ENERGY STAR[5] (http://www.energystar.gov/) (search under "Products") or Federal Energy Management Program (FEMP)-designated products[6] http://www1.eere.energy.gov/femp/technologies/procuring_eeproducts.html), unless it can be demonstrated that:

- Equipment meeting the requirements of ENERGY STAR® or FEMP is not "reasonably available"; and/or

- Equipment meeting the requirement is available but purchase of that equipment would not be life cycle cost-effective.

The following procedures for selection and design of HVAC systems shall be used:

- Ensure that passive design features (e.g., building orientation, shading, building envelope construction, daylighting (including energy-efficient windows), and insulation) are optimized to reduce heating and cooling loads. These passive techniques reduce the requirement to use complex, maintenance-intensive HVAC systems and equipment, thus reducing both energy usage and life cycle costs. Refer to Section 2.1 and Chapter 4 of this Manual for additional detail regarding these types of measures.

- Place special emphasis on keeping HVAC systems, including controls, simple and easy to operate and maintain. In general, the least complex of the technically feasible and cost-effective alternatives should be selected based on functional requirements, ease of maintenance, and the design energy budget. In other words, a system requiring extensive use of complex systems and controls should only be considered when there are no practical alternatives to obtain the design energy budget prescribed by ASHRAE 90.1-2007 (or most recent version) and other relevant standards.

- Consider the level and responsiveness of maintenance available at the specific facility and activity when selecting the HVAC system. Success of the HVAC system is dependent on acceptance of the system by the local staff responsible for routine O&M. The facility staff should be able to understand the operating principles and control logic,

[5] ENERGY STAR is a program jointly established by EPA and the U.S. Department of Energy (DOE). It certifies a wide variety of products (mostly in the retail consumer sector but also often applicable to Federal operations) that meet its standards for energy efficiency and reduced energy consumption.

[6] EO 13423 and EPAct 2005 require the use of ENERGY STAR or FEMP-designated products and equipment. Most of the energy efficiency standards for mechanical equipment that EPA would install in one of its buildings have been developed by FEMP. For each type of equipment, FEMP establishes minimum energy efficiency thresholds based on key operating characteristics or parameters. In most cases, the guidelines are for a range of products and include specific targets.

and maintenance of the system; similarly, system components should not require skills and knowledge beyond their capabilities. The EPA project manager may specify that the equipment supplier provide appropriate training for facility O&M staff. During the design phase, the project architect must ensure that adequate space will be provided for equipment maintenance and removal/replacement.

- The project HVAC engineer shall: (1) consider the types of systems currently installed at existing facilities when selecting systems for major renovations; and (2) seek to provide consistency in system types unless a simple, less-maintenance intensive system can be used in the new facility configuration.

6.2.1 Energy Simulation Models

Hourly energy simulation models are essential to evaluating HVAC designs for new buildings and major renovations of existing buildings that involve the HVAC system. All energy consumption and savings modeling performed pursuant to this section shall meet the following general requirements:

- The modeler shall follow the performance-based energy budgeting methodology specified in Chapter 11 and Appendix G of ASHRAE 90.1-2007 (or most recent version). Any deviances from this methodology *must* be thoroughly documented and approved by the EPA Project Manager prior to use.

For the types of facilities EPA operates, LEED-NC 2009 requires that hourly, whole building energy simulations be performed (this is a prerequisite and also a requirement to obtain points under the Energy Performance Credit).

- For laboratory facilities, the modeler shall follow the Laboratories for the 21st Century (Labs21®)[7] guidance document, *Laboratory Modeling Guidelines Using ASHRAE 90.1, Appendix G.* Energy usage and all contributing factors (e.g., heat losses, heat gains, internal heat loadings) must be calculated on an hourly basis, at a minimum, throughout the entire year (cooling and heating seasons, as applicable).

- The modeler shall submit an Energy Simulation Model Report (ESM Report) containing tabular and graphical summaries of the model results, summary of input parameters, list of assumptions, analysis of results, and recommendations. All raw data and model outputs shall be provided as PDF or other suitable file formats on a compact disk, in an Appendix to the ESM Report. These shall include, but not be limited to:

  - Assumptions regarding local weather statistics
  - Building usage profiles
  - Building envelope characteristics
  - Utility rates (all utilities that service the facility, whether locally based or distant, including transportation charges)
  - Equipment operating characteristics (e.g., temperature ranges, pressure drops, assumed or rated efficiencies, power consumption).

[7] Labs21 is a voluntary partnership program established by EPA and the U.S. Department of Energy (DOE). The program publishes best practice guidance on improving the environmental performance of U.S. laboratories.

Input parameters should be organized (preferably in a table) based on each major occupancy (e.g., laboratories, office space) in the building(s) being modeled. Takeoffs, such as walls, roof, and window areas, should also be tabulated in the ESM Report.

- Total energy consumption and savings shall be expressed in million British Thermal Units (MM BTUs) and in thousand BTUs per gross, usable square foot (kBTU/GSF). Electricity, natural gas, and steam inputs or purchases shall be converted to BTUs using standard factors (the conversion factors used shall be documented and submitted to EPA in the ESM Report).

6.2.1.1 Modeler(s)' Qualifications and Experience

The modeler(s) shall be an engineer, architect, building construction specialist, building O&M specialist, or other similarly qualified individual. Substantial competency and experience with the energy modeling software referenced herein is essential. The following credentials are not required but are highly desirable:

- Applicable licensures (e.g., Professional Engineer, American Institute of Architects)
- Membership and active participation in organizations such as ASHRAE or the Association of Energy Engineers (AEE)
- Leadership in Energy and Environmental Design (LEED®) Accredited Professional certification and extensive experience designing and/or operating high performance, sustainable buildings
- Experience conducting energy simulation modeling for at least five projects, includingat least one other EPA facility.

Résumés for all proposed modeler(s) shall be submitted to EPA for review.

6.2.1.2 Software

The modeler shall utilize an annual hourly energy simulation software package that has been tested in accordance with ANSI/ASHRAE Standard 140*, Building Thermal Envelope and Fabric Load Tests*. The software must be capable of explicitly modeling:

- Hourly energy use over a full year (8,760 hours per year)
- Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermal equipment set points, thermostat set points, and HVAC system operation, defined separately for each day of the week and holidays
- Thermal mass effects
- Ten or more thermal zones
- Part-load performance curves for mechanical equipment
- Capacity and efficiency correction curves for mechanical heating and cooling equipment
- Air-side and water-side economizers with integrated control.

The software may directly determine energy and power costs or produce hourly reports of energy use, by energy source, suitable for determining energy and power costs separately. Alternatively, the software may develop design load calculations to determine potentially required HVAC equipment capacities and air-side and water-side flow rates.

The EPA project manager shall approve the software to be used for energy simulation modeling. Refer to DOE's website, *Qualified Software for Calculating Commercial Building Tax Deductions*, for additional information. The modeler may use any of the programs and applicable versions contained on the most recent version of this list, or may propose a different software for approval by EPA. Unless specifically approved by EPA, public domain or commercial software shall utilize the EnergyPlus™, DOE-2.1E, or DOE-2.2 simulation engines.

The modeler shall utilize a graphical, commercial, or other third-party interface program (e.g., Visual DOE™, e-Quest™, Green Building Studio™, Google SketchUp with OpenStudio) to enhance visual interpretation of the model output results. . The modeler may use any ancillary software required for specific system performance or cost modeling (e.g., WINDOW5 for window construction, TRNSYS for solar energy systems, RADIANCE for daylighting, BLCC for life cycle cost analyses). For whichever models are used, results and supporting documentation at a similar level of detail to that provided for the energy consumption simulation models shall be submitted to EPA for review.

6.2.1.3 Quality Assurance/Quality Control (QA/QC) Plan

The modeler shall develop a QA/QC Plan for the specific energy simulation modeling tasks being requested by EPA. A single QA/QC Plan may be used for multiple projects or sites if the modeling being conducted is similar. The QA/QC Plan shall be structured around project-specific objectives agreed upon between EPA, the project design team, and the modeler prior to setting up and running the model.

The QA/QC Plan should include standard or project-specific checklists to ensure the accuracy and completeness of all input data and the realism and appropriateness of model output results. Criteria for rejecting input and output data, and causes for recalibration and/or re-execution of the model shall be defined in the QA/QC Plan. The QA/QC Plan shall identify the roles and responsibilities of those individuals who will:

- Organize and input data to the model
- Run the model and generate results
- Check the input data, output results, and procedures used to ensure that the proposed building(s) and systems have been accurately described and modeled
- Analyze the results and provide recommendations to EPA.

6.2.1.4 Building Systems to be Modeled

All significant and relevant building systems shall be incorporated into the model. This may include any combination of the following:

- Building envelope, i.e., walls (attached and freestanding), windows and doors, floor (heat exchange with the ground), and roof
- Lighting systems
- Heating systems (boilers, radiant heaters, heating coils, geo-exchange heat pumps)

- Ventilation systems (air handlers, supply and exhaust ductwork, terminal boxes)
- Fume hoods and accompanying exhaust systems
- Cooling systems (chillers, chilled water circulation loops, direct expansion [DX] and split systems, and other air conditioning devices)
- Domestic hot water heating equipment
- Process steam usage
- Solar hot water heating systems
- Cooling towers.

All thermal zones defined for the purpose of modeling shall be thoroughly described graphically and in the ESM Report text. Simplifying assumptions for thermal zones shall be subject to approval by the EPA Project Manager.

Certain software packages may not be capable of effectively simulating process loads. The modeler shall propose to EPA how the effects of process and receptacle loads, including laboratory equipment, will be evaluated. When comparing simulated building energy consumption against applicable baseline values (e.g., ASHRAE 90.1), process and receptacle loads are normally omitted. If process and receptacle loads are developed based on generalized assumptions (e.g., Watts per square foot), such assumptions shall be consistent with relevant guidelines provided by the Labs21® Program.

6.2.1.5 Modeling Sequence

In general, the modeler shall first evaluate the effects of various energy efficiency measures involving the building envelope and lighting systems. Based on the results of these models, a cumulative model shall then be prepared, which will comprise the new Baseline Scenario. HVAC equipment and systems alternatives shall next be evaluated, and the selected measures shall be combined into a cumulative HVAC model. This cumulative HVAC model is then compared to the new Baseline Scenario to derive the energy savings and associated cost savings. Alternatives to the above-described approach may be approved by the EPA project manager on a case-by-case basis.

6.2.1.6 Modeling Stages and Iterations

Unless otherwise requested by the EPA project manager, the simulation model shall be prepared and run at least three times during the project:

- During the conceptual/planning process
- Following completion of the detailed design
- Following completion of the construction specifications package.

This will allow important assumptions to be updated and refined, while providing EPA with data and results for decision-making at key junctures of the project. During each stage, the modeling software will likely require a number of iterations in order to converge to the apparent optimal design or operating specifications. Key parameters that often need to be varied to iterate to a solution include:

- Building envelope characteristics and orientation
- Size and type of central HVAC plant
- Type of distribution systems for fresh air, chilled water, hot water
- Control set points for HVAC energy conversion and distribution equipment
- Daylighting apertures and controls
- Efficiencies of lighting fixtures and lamps
- Use of, and percentage contribution from, renewable energy sources (e.g., geoexchange heat pumps, solar heating or photovoltaic systems, wind turbines).

For projects that are pursuing LEED-NC 2009 Credit EA 5, [Energy] Measurement and Verification using Option D (Whole Building Calibrated Simulation Savings Estimation), an additional simulation run(s) will be required after the project O&M period commences. To perform this additional simulation, the modeler shall substitute actual operating conditions and parameters for the estimated parameters used in the original simulation, to document and verify that the expected energy performance is being achieved. Additional guidelines can be found in the LEED-NC or LEED-EB:O&M Reference Guides.

As mentioned previously, the modeler shall document all initial parameter values and iterative values (including the ultimate convergence point), as well as the underlying justification for those parameters, in the modeling package submitted to EPA.

6.2.1.7 "Shoebox Models"

In the early (planning) stages of the design, the modeler may use a "shoebox" approach to rapidly evaluate different alternatives and select the most promising alternative(s) from among that initial set. A "shoebox" energy simulation model typically involves a default building in the general shape of a shoebox (length approximately twice the width) having the same approximate parameters to those anticipated in the final design:

- Floor areas
- Occupancy schedules
- Space utilization patterns (e.g., offices, kitchens, meeting rooms, storage, corridors/informal meeting areas)
- Indoor thermal zones.

Typically, a baseline scenario (i.e., minimally code-compliant) and more energy-efficient alternatives are modeled using the shoebox to provide a first-cut analysis of the projected energy consumption and energy cost savings.

6.2.1.8 Validation and Verification

Where available and appropriate, the modeler may use actual performance data from similar facilities or realistic scenarios to validate the results generated by the simulation model runs. Results that appear counterintuitive are not necessarily incorrect, but must be discussed in the ESM Report that accompanies the modeling package submitted to EPA. Similarly, verification of random or targeted calculations using spreadsheets, MathCad™, or other tools should be submitted, especially in support of crucial results and/or where the energy use simulation model is operated at or beyond the limits of its capabilities.

6.2.1.9 Consistency with LEED® Documentation Requirements

Because projects may be proposed for certification under the LEED® rating system either at the time of completion or at a future time, the results of all energy simulation modeling shall be compiled and presented in the format required by the applicable LEED® system (e.g., New Construction [NC], Existing Buildings: O&M).

6.2.1.10 "Moving" Baseline

For capital projects that are funded and implemented in a phased manner, the baseline scenario for energy savings calculation shall be "moving" (i.e., updated based on the assumed completion of each phase). For example, if a project consists of three phases:

- The initial (Phase 1) baseline shall be the existing conditions
- The Phase 2 baseline shall be based on conditions (actual or expected) upon completion of all Phase 1 retrofits
- The Phase 3 baseline shall be based on conditions (actual or expected) upon completion of all Phase 2 retrofits.

6.2.1.11 Model Calibration

The initial baseline scenario shall be calibrated using the most recent, consecutive 12 months of data, including: (1) actual operating data from building systems; and (2) costs based on actual utility bills. The level of variance between the baseline estimated energy consumption and cost and the actual utility data shall be quantified and reported by the modeler.

6.2.1.12 Parametric Modeling

When analyzing the relative contributions to, or effects of, different components of a dependent variable (e.g., heating load, cooling load), EPA may request that parametric modeling be performed. In parametric modeling, individual components are one-by-one set equal to zero, and the relative effects on the dependent variable are compared. In another application of parametric modeling, the relationship between incremental energy efficiency and incremental savings can be assessed. For example, the incremental savings of substituting spectrally-selective glass for ordinary glazing, at various total window area values, can be evaluated, leading to a decision of when and where to use the spectrally selective glazing. (For a more in-depth discussion of parametric modeling and its potentially applicability, refer to M. Rosenbaum, *Understanding the Energy Modeling Process—Simulation Literacy 101,* The Pittsburgh Papers, 2003, www.buildinggreen.com).

6.2.2 Computational Fluid Dynamics Modeling

Computational fluid dynamics (CFD) models shall be considered for predicting indoor air quality (IAQ) parameters in spaces with complex airflow regimes and/or potentially hazardous conditions. For EPA, the most likely future application will be modeling airflows, contaminant concentrations, and other factors that influence the selection and design of fume hoods and laboratory ventilation systems. For example, CFD can be used to confirm that required face velocities are being achieved throughout the hood face cross-sectional area, or to determine if fume hood tracer tests would be required or advisable and provide data to aid in planning those tests. In addition, CFD models can also be successfully applied to analysis of other workspaces, particularly to situations where conformance with applicable ASHRAE standards (e.g., 55 and 62.1) is potentially affected due to complex room geometries, internal heat sources, operating schedules, etc. Other potential applications for which use of CFD shall be considered include:

- Areas with large equipment cooling loads
- Adjacent rooms required isolation to prevent cross-contamination; and
- Rooms and spaces that require high inlet ventilation flows but also have small or dispersed exhaust outlets.

The project mechanical engineer shall determine whether CFD is required or highly advisable for a particular project and submit a work plan or proposed methodology to the EPA project manager. The EPA project manager will review the work plan/methodology and either approve it for implementation or return it to the mechanical engineer with comments and requested modifications.

The following requirements apply to any applications of CFD at EPA facilities:

- The project mechanical engineer or modeler shall follow the relevant CFD guidelines outlined in the most recent edition of the ASHRAE *Fundamentals* Handbook, Chapter 34, "Indoor Environmental Modeling."
- Prior to beginning modeling, the project mechanical engineer or modeler shall prepare a technical memorandum ™ outlining the objectives of the modeling approach (e.g., evaluating thermal comfort and/or indoor air quality, assessing fume hood leakage or containment capability, determining the impacts due to an uncontrolled spill or release). The EPA project manager shall review and approve the TM or return it to the engineer/modeler for revision.
- The modeler shall select a flexible, validated, and widely used computer software tool to perform CFD simulations. The tool shall use finite difference, finite element, or similar type of mesh modeling software designed to iterate to a solution based on the principles of conservation of mass, energy, and momentum and computing variables such as airflow volume and mass, contaminant mass, temperature, pressure, etc. at each node in the mesh. At the inception of the modeling effort, the project mechanical engineer shall recommend the type of model and software expected to be most suitable to attain the project's objectives. These may include models that employ the following types of turbulent transport algorithms: (1) steady-state, Reynolds average approximations of the Navier-Stokes equation (e.g., k-epsilon algorithms[8]); or (2) large eddy simulations (LES). In situations where averaged values at mesh nodes are not sufficiently accurate, transient phenomena (e.g., leakage from fume hoods) are a concern, and overall computing run time is less important, use of LES models generally will be preferred. The EPA project manager must approve the software package <u>prior</u> <u>to</u> initiation of modeling.
- The mesh size (i.e., distances between nodes) shall be selected based on project objectives/data quality requirements and scope of the analysis. In generally, spacing between nodes of greater than six inches should not be used, and in areas where greater granularity of data is required (e.g., to assess parameter variation in the vicinity of fume hoods), mesh size shall be reduced to one inch or less (or another value approved by the EPA project manager).[9] The modeler shall also take all appropriate steps to ensure that

[8] k represents turbulent kinetic energy of the fluid, and epsilon represents the dissipation rate of turbulent energy.

[9] Ratcliff, M.A., *Use of Computational Fluid Dynamics (CFD) for Laboratory Air Flow*, prepared for the University of Washington, September 11, 2009.

the solution remains grid-independent to the most appropriate extent possible, given project objectives and reasonable computing time limits.

- When selecting time step intervals for the simulation model, the project mechanical engineer shall ensure that the time steps are small enough to enable convergence to a solution. If the modeler finds that, despite best efforts, the model is not converging to a solution and/or not generating credible output data, an alternate software package or analysis methodology shall be proposed for EPA's review and approval. The modeler shall take all appropriate steps to ensure that the solution remains time step-independent to the most appropriate extent possible, given project objectives and reasonable computing time limits.

- The modeler shall include in the model a11 internal heat sources and sinks, at a minimum, all workers, HVAC equipment, lighting, computers, etc. Boundary conditions (e.g., walls, windows, furniture, supply diffusers, exhaust plenums, and equipment) also must be carefully established before running the CFD model. The modeler shall provide EPA with written justification for all boundary conditions.

- Because direction, velocity, and temperature patterns can vary greatly in the immediate vicinity of supply air diffusers, even the type of fine mesh model described above is usually inefficient. The modeler must take into account the expected throw and direction of the diffuser (including Coanda effects), based on manufacturer data, field measurements, or other acceptable method to supplement the CFD model at/near the diffuser outlets.

- The modeler shall prepare and submit to EPA output data from the model that clearly and accurately represents key results. This may consist of some combination of plan views with iso-concentration lines, cross-sectional cuts with iso-concentration lines, and three-dimensional perspective illustrations of plume volumes. After the initial data is post-processed from the model, the modeler shall provide a few sample figures to EPA for review and approval, before generating the remaining figures for the dataset.

- To the extent relevant, the modeler shall implement the detailed verification, validation, and output reporting protocols described in the ASHRAE *Fundamentals* Handbook, Section 34, pp. 34.9 – 34.14. These protocols were originally described in the paper by Chen, Q. and J. Srebric, 2002, *A Procedure for Verification, Validation, and Reporting of Indoor Environment CFD Analyses,* International Journal of HVAC&R Research, Vol. 8, No. 2, pp. 201-216. In particular, the output residual for mass and residual for energy (i.e., the error associated with each simulation) shall be evaluated using the formulas on p. 34.11 of the *Fundamentals* Handbook, to document that convergence has been achieved. Depending on the modeling objectives, additional convergence criteria may need to be defined and evaluated, as discussed on p. 34.11 of the *Fundamentals* Handbook. An error and uncertainties analysis must be included in the Modeling Report provided to the EPA project manager.

6.2.3 Wind Tunnel Modeling

Wind tunnel modeling of exhaust plume behavior shall be conducted in a boundary-layer type wind tunnel, using a scale model of the subject building and surrounding buildings.[10] The scale model of the facility and neighboring facilities within a 1,000-ft to 3,000-ft radius shall be constructed and placed on a turntable. Model stacks shall be installed at the appropriate

[10] Petersen, R.L., B.C. Cochran, and J.W. LeCompte, *Specifying Exhaust Systems that Avoid Fume Re-entry and Adverse Health Effects*, ASHRAE Transactions, HI-02-15-3, 2002.

locations, and supplied with a tracer gas mixture (e.g., an ethane and nitrogen mixture), with a density similar to room temperature air. Sources with a temperature hotter than ambient air, such as diesel generators and boilers, shall be supplied with a gas mixture having a density lighter than ambient air (e.g., ethane and helium). Flow conditions at the stack release point(s) must be fully turbulent, and the decrease in turbulence (and increase in wind speed) normally observed with increasing elevation must be present. Precision mass flow controllers shall be used to monitor and regulate the discharge velocities. Other key parameters such as wind tunnel airflow rates and air velocities must also be measured.

Concentration sampling points (receptors) shall be installed at the locations of interest for the particular facility and surrounding properties being evaluated (i.e., air intakes, entrances, operable windows, courtyards, etc.) Concentrations of the tracer gas at each of these critical locations will be measured under a range of wind direction and wind speed values to identify the maximum normalized concentration and the root-mean-square normalized concentrations ("normalized" concentrations are the concentrations divided by the emissions rate of the source(s)).. Sufficient data shall be obtained to develop an empirical equation that describes the normalized concentrations as a function of wind speed and direction. Scenarios shall be run for all source/receptor combinations of interest. The resulting data shall be used to generate summary tables and graphs depicting contaminant transport patterns. A report shall be generated containing the summary tables and graphs; test methodology description; list of key assumptions; sources of potential error; and findings, conclusions, and recommendations.

6.2.4 Outdoor Design Conditions

Outdoor air design criteria shall be based on weather data tabulated in the most recent edition of the ASHRAE *Handbook—Fundamentals*, Chapter 28. Winter design conditions shall be based on the 99.6 percent column dry bulb temperature. Summer design conditions for sensible heat load calculations shall be based on the 0.4 percent dry bulb temperature with its mean coincident wet bulb temperature. Design conditions for the summer ventilation load and all dehumidification load calculations shall be based on the 0.4 percent dew point with its mean coincident dry bulb temperature.

6.2.5 Indoor Temperature and Humidity Requirements

Temperatures shall conform to ASHRAE 55, the guidelines contained in this section (see below), and local commercial equivalent temperature levels and operating practices, as relevant and applicable. The overall goal shall be to maximize occupant satisfaction for the maximum possible percentage of the occupant population. These temperatures shall be maintained throughout the occupied spaces, regardless of outside temperatures, during the hours of normal operation of the facility.

ASHRAE 55 addresses thermal comfort of people within buildings. The standard defines ranges of indoor temperatures and relative humidity levels for which, in general, 80 percent of a typical cross-section of people will not report dissatisfaction. Input data for developing these ranges is developed largely based on occupant surveys, using a specific methodology proposed by ASHRAE, called the Predicted Mean Vote/Predicted Percentage Dissatisfied index. The ranges may be derived using lookup graphs or computer models (the computer models usually yield more precise information). Other variables that influence occupant comfort (e.g., air speed and drafts, thermal radiation off indoor surfaces, and non-steady state temperature fluctuations) are also factored into the methodology.

6.2.5.1 Design Temperatures

Target set point and design temperatures for summer (cooling season) and winter (heating season) occupancy are presented in Table 6-1 below:

Table 6-1: Target Set Point and Design Dry Bulb Temperatures (T_{db})

Indoor Space Type	Cooling Season Occupancy		Heating Season Occupancy	
	T_{db}, Target Set Point (°F)	T_{db}, Design (°F)	T_{db}, Target Set Point (°F)	T_{db}, Design (°F)
General Office	75 ± 2	70	72 ± 2	77
ADP Rooms[1]	72 ± 2	67	72 ± 2	77
Corridors	75 ± 2	70	72 ± 2	77
Building Lobbies	75 ± 2	70	72 ± 2	77
Toilets	75 ± 2	70	72 ± 2	77
Locker Rooms	78 ± 2	73	70 ± 2	75
Electrical Closets	78 ± 2	73	55[3]	60
Mechanical Spaces	95[2]	90	55[3]	60
Electrical Switchgear	95[2]	90	55[3]	60
Elevator Machine Room	(78 ± 2)[2]	73	55[3]	60
Emergency Generator Room	104[2]	99	65 ± 2	70
Transformer Vaults	104[2]	99	55[3]	60
Stairways	85[2]	80	55[3]	60
Communications/ Telecommunications Frame Room	75 ± 2	70	72 ± 2	77
Storage Room	85[2,4]	80	(65 ± 2)[4]	70
Conference Room	75 ± 2	70	72 ± 2	77
Auditorium	75 ± 2	70	72 ± 2	77
Kitchen[5]	75 ± 2	70	72 ± 2	77
Cafeteria[6]	75 ± 2	70	72 ± 2	77
Laboratory Work Spaces	(70 – 74)[7]	67	(70 – 74)[7]	77

1. Conform with equipment manufacturer's requirements if more stringent. An in-room display and monitoring device, such as wall-mounted temperature and humidity chart recorder, shall be provided.
2. Maximum temperature allowable. Space to be mechanically cooled, if necessary.
3. Minimum temperature in the building must be 55°F, even when unoccupied.
4. Guideline only. Temperature requirements shall be established based on the type(s) of materials to be stored.
5. Automatic temperature control shall be provided.
6. System shall be designed for process cooling. Cooling system shall be a dedicated, independent system.
7. Based on the Labs21® recommended dead band temperature range in P. Mathew, *Metrics and Benchmarks for Energy Efficiency in Laboratories*, October 2007, Appendix A. Design temperatures are ± 5°F from the average (i.e., 72°F).

ADP – Automatic data processing, °F – degrees Fahrenheit

The designer shall assume that during non-working hours, heating temperatures will be reset to no higher than 55°F, and that air conditioning will not be provided (except in the morning to pre-cool the space, as required to achieve the target set point by 8 A.M. or site-specific start time). Thermostats shall be secured from manual operation by a key or locked cage. Simultaneous heating and cooling are not permitted, except under the conditions outlined in Section 8.3.1 of this Manual. Independent temperature control shall be provided for areas having excessive heat gain or heat loss, or that are affected by solar radiation at different times of the day.

For non-laboratory facilities, the interior thermostatic control zones must not exceed 1,500 square feet (ft^2) per zone for open office areas or a maximum of three offices per zone for closed office areas. Perimeter thermostatic control zones shall not exceed 300 ft^2 and shall be no more than 15 feet from an outdoor wall along a common exposure. Corner offices shall be dedicated zones.

LEED Opportunities for Indoor Climate Control:

- **EPA facilities must meet the minimum ventilation standards of ASHRAE 62.1 (latest version) to become LEED-NC 2009 certified (i.e., this is a prerequisite). In addition, facilities can earn points under the Indoor Environmental Quality category for a 30 percent or greater improvement over the ASHRAE 62.1-required ventilation rate (refer to call-out box in Section 6.4.1).**
- **EPA facilities can earn one point toward LEED-NC 2009 certification if individual comfort controls (e.g., adjustable airflow registers, thermostats) are provided for at least 50 percent of the building's occupants.**
- **EPA Facilities can earn one point toward LEED-NC 2009 certification if they meet ASHRAE 55 minimum standards (latest version). Because new EPA facilities (and major renovations to existing facilities) that meet the Federal Guiding Principles for high-performance, sustainable buildings are required to meet ASHRAE 55 minimum standards, they thus will automatically receive one point under LEED-NC 2009. Facilities can earn an additional point if they install and operate a permanent monitoring system (based on occupant surveys, <u>not</u> equipment) to assess and monitor thermal comfort within the facility. The monitoring system must conform with all requirements contained in ASHRAE 55 and in the LEED Reference Guide.**

6.2.5.2 Design Relative Humidity

Seasonal design relative humidity values shall be as follows unless otherwise designated by the project requirements:

- <u>Conformance with ASHRAE Standard</u>: Except where indicated differently below, relative humidity levels for each season shall be maintained in accordance with Chapter 8, Figure 5 of the ASHRAE Fundamentals Handbook, *Summer and Winter Comfort Zones.*

- <u>Cooling Season</u>: The design 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 the space through the normal cooling process.

- <u>Heating Season</u>: Except where it can be substantiated from records or engineering computations that the indoor relative humidity will be less than 30 percent, winter humidification for personnel comfort and health shall not be provided. Where the probable occurrence of these conditions has been substantiated, a design relative humidity of 30 percent shall be used in establishing minimum requirements for humidification equipment.

6.2.6 Testing and Balancing (TAB) of Mechanical Systems

An independent air TAB contractor shall be retained 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:

- Whose specialty is testing and balancing environmental systems

- That is a member of the Associated Air Balance Council (AABC) and/or the National Environmental Balancing Bureau (NEBB)

- That has satisfactorily balanced at least three systems whose type and size are comparable to those of the project.

The TAB contractor shall be registered in the state in which the project is located.

The TAB scope of work shall include, but not necessarily limited to, the following systems:

- All air-conditioning supply and return systems
- Air exhaust systems
- Laboratory fume hoods (hereinafter "fume hoods") supply and exhaust systems (*a separate firm that specializes in TAB of fume hood systems may need to be contracted*)
- All hydronic systems
- Gas and compressed air systems.

Fume hood TAB shall be in accordance with the requirements and criteria specified in Section 6.3.9 and Appendix C of this Manual.

HVAC air and water distribution systems shall be provided with permanently installed and calibrated TAB devices. A listing of the minimum required monitoring parameters is contained in Table 8-3.

At the completion of the TAB activities, the TAB contractor shall submit a report for EPA's approval, which conforms in format and content to the requirements of the AABC and/or the NEBB. The report shall reflect all aspects of the TAB 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.

Refer to Appendix B of this Volume for EPA's building commissioning requirements (including aspects of commissioning specific to TAB issues).

6.2.7 Balancing Devices

In order to properly and adequate test and balance an HVAC system, as described in Section 6.2.6 above, certain components are required. These components consist of velocity (pitot tube) traverses, air volume balancing dampers, and hydronic balancing valves, which are discussed further in the sections below.

6.2.7.1 Velocity (Pitot Tube) Traverses

Ductwork at key air velocity measuring locations shall be designed to accommodate a standard pitot traverse probe. Pitot tube traverses shall be performed in accordance with the most-recent editions of the following standards:

- ASHRAE Fundamentals Handbook
- Air Movement and Control Association (AMCA) Publication 203, *Field Performance Measurement of Fan Systems.*

To facilitate pitot tube traverses, the project mechanical engineer shall ensure that the maximum amount of straight duct runs are present upstream and downstream from each probe penetration point. Air straighteners may be required where sufficient lengths of straight duct cannot be installed.

Wherever factory-fabricated, air volume-measuring stations (e.g., Wilson Grids) are used, the effectiveness of these devices shall be checked using a manually-inserted pilot tube at several locations through the duct cross-section. The probe access port must be situated in close proximity to the air volume-measuring station.

6.2.7.2 Air Volume Balancing Dampers

Air volume balancing dampers ("balancing dampers") shall conform to applicable SMACNA specifications. Wherever possible, locate and orient balancing dampers such that access is limited to facility HVAC maintenance personnel (i.e., not operable by building occupants).

Manually-operated, opposed-blade or single-blade (as appropriate based on duct size) balancing dampers shall be installed in all supply, return, and exhaust air main ducts and branch takeoffs. Balancing dampers shall not be located immediately behind diffusers and grilles, because of potential noise and changes to flow characteristic when throttled. Each balancing damper shall be adjustable with a locking quadrant handle or regulator, as well as end bearings that have sufficient strength and rigidity for the pressures being controlled. The locking quadrant must be outside the vapor seal of the insulation.

Because they generally provide little or no control of volumetric airflow in ducts, splitter devices and adjustable extractor doors shall not be used for airflow balancing. Balancing dampers should not be included in VAV systems; VAV systems designed using the static regain method and equipped with properly-sized VAV terminal units are inherently self-balancing.

6.2.7.3 Hydronic System Balancing Valves

For fan-coil units, each hot or chilled water coil entering the unit shall be equipped with its own balancing valve. Balancing valves shall ave inlet and outlet taps for pressure measurement, and shall be pre-calibrated by the manufacturer by measuring the resistance at various positions against known flow quantities. The valve shall have a graduated scale or dial to indicate the degree of opening. For constant flow systems, spring-loaded piston valves that maintain 25 percent flow as long as the pressure differential is within the manufacturer's suggested range may be employe. A strainer shall be installed upstream from each spring-loaded piston valve to prevent dirt or debris from clogging the valve.

Balancing valves shall be located on the "leaving" side of the hydronic branch, terminal, zone, riser, or main. Balancing valves and associated measuring meters shall provide an accuracy of at least ±5 percent of its operating range, down to a pressure drop of 12 inches of water with the valve wide open. All balancing valves shall be installed in accordance with the manufacturer's recommendations regarding the minimum straight lengths of pipe upstream and downstream from the valve.

Three-way mixing/diverting valves should be used only for (1) two-position switching of water flow, or (2) modulating control of cooling tower water. In other situations, two-way modulating valves and/or variable flow pumping should be used instead to increase energy efficiency, improve control, and prevent exceedance of design flow when the valve is at mid-position**.**

6.2.8 Service Access and Clearances

Sufficient horizontal and vertical clearances shall be provided around all HVAC system equipment, as recommended by the manufacturer and in compliance with local code requirements for routine maintenance. Access doors or panels shall be provided for ventilation equipment, ductwork, and plenums to facilitate inspection and cleaning

Mechanical equipment rooms shall have clear ceiling heights of not less than 12 feet. Catwalks with stairways shall be provided for all equipment that cannot be maintained from floor level. Where maintenance requires the lifting of heavy parts (100 pounds or more), hoists and hatchways shall be installed.

Mechanical rooms shall be configured with clear circulation aisles and adequate access to all equipment. Mechanical room(s) shall have adequate doorways (or areaways) and staging areas to permit the replacement and removal of equipment without the need to demolish walls or relocate other equipment. Sufficient space areas, in accordance with the manufacturers' recommendations, for maintenance and removal of coils, filters, motors, and similar devices shall be provided.

Chillers shall be located to permit pulling of tubes from all units. The clearance shall equal the length of the tubes plus 2 feet. Air handling units (AHUs) require a minimum clearance of 2.5 feet on all sides, except the sides on which filters and coils are accessed (where a 2-foot clearance is acceptable).

Access to roof-mounted equipment shall be via stairways and not via "ship's ladders."

6.2.9 Mechanical Rooms

All mechanical rooms must be mechanically ventilated to maintain room space conditions, as indicated in ASHRAE 62.1 and ASHRAE 15. Locations and characteristics of water lines shall comply with the requirements of NFPA 70, Chapter 1. Mechanical rooms shall have floor drains in proximity to the equipment they serve, to reduce water streaks or drain lines extending into aisles. (*Floor drains shall discharge to the facility's industrial/process sewer system, and not to any storm drains*). Mechanical rooms shall not be used as return air, outdoor air, or mixing plenums.

Rooms that house emergency generators shall meet the requirements of NFPA 110 and meet the combustion air requirements of the equipment, OSHA requirements, and state and local air emissions/air quality regulations. These rooms must be ventilated sufficiently to remove heat gain from equipment operation and maintain the ambient temperature requirements in Table 6-1 during operations (including periodic turn-over testing and idling). Supply and exhaust louvers shall be located to prevent short-circuiting of airflow. Generator exhaust shall be carried up to roof level in a flue, constructed and installed in conformance with the manufacturer's recommendations and local code requirements. Horizontal exhaust through a building wall must be approved by EPA.

A locking key system shall be provided for all mechanical room spaces. Some or all of the following basic intrusion detection devices shall be provided:

- Magnetic reed switches for interior doors and openings
- Glass break sensors for windows up to scalable heights
- Balanced magnetic contact switch sets for all exterior doors, including overhead/roll-up doors.

Rooftop-installed intrusion detection equipment shall also be considered.

6.3 Ventilation Systems

This section contains the general requirements for ventilation systems at all types of EPA facilities. Additional, specialized requirements that apply to laboratory ventilation systems are discussed in Sections 6.3.9 and 6.3.10. Non-laboratory spaces shall comply with the requirements of ASHRAE 62.1 (most recent version). Laboratory spaces shall comply with the most recent edition of the Best Practice Guide, *Optimizing Laboratory Ventilation Rates*, and/or other relevant guidelines issued by Labs21.

6.3.1 Duct Design

6.3.1.1 General Requirements

Ductwork systems shall be designed for efficient distribution of air to and from the conditioned spaces. The following additional factors shall also be considered during the design process:

- Noise
- Available space
- Maintenance
- Air quality (inside the conditioned space)
- Air flow and volume
- Minimization of leakage
- Optimum balance between expenditure of fan energy (which is linked directly to annual operating cost) and duct size (which is linked to initial investment).

As described in Chapter 9 of this Manual, duct smoke detectors shall be installed in accordance with NFPA 90A requirements. Exposed ducts, piping, and conduits are not permitted in office space.

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 most recent editions of the following:

- ACGIH, *Industrial Ventilation Manual*
- U.S. Department of Defense (DoD), Unified Facilities Criteria (UFC) 3-410
- ASHRAE, *Fundamentals* Handbook
- NFPA 90A
- NFPA 91
- NFPA 96
- SMACNA, *HVACR Duct Construction Standards—Metal and Flexible*
- SMACNA, *Fibrous Glass Duct Construction Standards*

- SMACNA 1520, *Round Industrial Duct Construction Standards*
- SMACNA, *HVACR Systems—Duct Design Manual*
- ASHRAE 62.1
- ANSI/AIHA Z9.2
- ANSI/AIHA Z9.5
- SMACNA, *Indoor Air Quality (IAQ) Guidelines for Occupied Buildings Under Construction*.

In addition, the Labs21 program has developed a concise set of guidelines pertaining to the design of ductwork systems for laboratories, which shall serve as the standard for EPA laboratory facilities (except where in conflict with the above codes and standards).

6.3.1.2 Ductwork Fabrication

Ductwork for air supply, return air, and general exhaust shall be fabricated of sheet metal (galvanized steel, stainless steel, or aluminum), or fiberglass-reinforced plastic that meets NFPA, IBC, and local fire code ratings. "Flex duct" may be used for low-pressure ductwork downstream of the terminal box in office spaces. The length of the flex duct shall not exceed the distance between the low-pressure supply air duct and the diffuser plus 20 percent, to permit relocation of diffusers in the future while minimizing replacement or modification of the hard ductwork distribution system. In addition, flex duct runs shall not exceed 10 feet, nor shall they contain more than two bends. Joint sealing tape for all connections shall be of reinforced, fiberglass-backed material with field-applied mastic. Use of pressure-sensitive tape is not permitted.

Duct linings or coverings shall be of non-combustible 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), when tested in accordance with ASTM E84. Use of porous duct liners that can collect dirt and moisture are not acceptable for use under any condition. Where such liners are already in use, and particularly in areas close to humidification or dehumidification (cooling) equipment, the lining shall be removed, unless it is coated or sealed to prevent fiber loss.

The sheet steel used to fabricate ducts typically has a thin petroleum or fish oil coating, which is primarily intended to inhibit corrosion during transportation and storage of the steel. Use of these coatings often results in the following issues:

- The coating may trap dirt particles
- Some people find the odor objectionable
- Air emissions from the coating can affect individuals with asthma or allergies.

One potential solution is to remove the coating from the duct using a mild cleaning agent, such as a household dishwashing liquid, in conjunction with a heated, high-pressure sprayer.

Harvard University, Duke University, and the University of Nevada have conducted studies of typical air stream materials, which demonstrate that all typical materials used in ducts can experience microbial growth when the proper conditions exist. Microbial growth can occur on any duct material if the proper moisture levels, temperature, and nutrients are present (refer to the

North American Insulation Manufacturers Association [NAIMA] website for additional information). Metal surfaces and cut liner with durable surfaces may be cleaned more easily, without fear of damaging the surface material. NAIMA has a guide on its website (www.naima.org) covering cleaning of fibrous glass or lined sheet metal.

To minimize potential generation of volatile organic compounds (VOCs) from duct sealants, all fiberglass ductwork shall be assembled using UL 181-approved duct tape. The tape shall be applied to the exterior of the duct board such that it is not exposed to the air stream.

6.3.1.3 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 sufficiently low dew point such that condensation will not occur (as verified by engineering calculations). Return and exhaust air ductwork should be insulated where condensation may occur along duct runs that route air through unconditioned areas.

Insulation thermal resistance values shall meet or exceed the minimum requirements per the most recent edition of the International Energy Conservation Code (IECC).

Fibrous glass insulation materials shall contain the minimum possible content of formaldehyde-based resin binder materials. Insulation containing asbestos is prohibited. The possibility that water infiltration will cause physical damage to, or loss of, thermal characteristics of pipe and duct 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 (factory- or field-installed) or a hard cement finish.

The EPA Comprehensive Procurement Guidelines (CPGs), described in Table 6-2 below, shall be followed wherever applicable, feasible, and cost-effective. These requirements must be included in project bid specifications and directly communicated to the project engineer and mechanical contractor.

Table 6-2: EPA's CPG for Building Insulation Products[1]

Products/Materials	Minimum Required Post-Consumer Content	Minimum Required Total Recovered Materials Content
Rock Wool (Slag)	NR	75%
Fiberglass (Glass cullet)	NR	20% – 25%
Cellulose Loose Fill and Spray-On (Post-consumer Paper)	75%	75%
Perlite Composite Board (Post-consumer Paper)	23%	23%
Plastic Rigid Foam (Poly-isocyanate/Polyurethane)	NR	9%
Plastic Foam-in-Place	NR	5%
Glass Fiber, Reinforced	NR	6%
Phenolic Rigid Foam	NR	5%
Plastic, Non-woven Batt (Recovered and/or Post-consumer Plastic)	NR	100%

1. Last updated on August 15, 2006.

NR – no requirement

6.3.1.4 Air Distribution

Supply, return, and exhaust air ducts shall be designed and constructed to allow no more than 3 percent leakage of total airflow in systems up to 3 inches of water column [in WC] pressure). In systems that operate between 3 in WC and 10 in WC, ducts shall be designed and constructed to limit leakage to 0.5 percent of the total air flow. All ductwork joints and all connections to air handling and air distribution devices shall be sealed with mastic—including all supply and return ducts, any ceiling plenums used as ducts, and all exhaust ducts. Energy consumption, security, and sound attenuation shall be major considerations in the routing, sizing, and material selection for the air distribution ductwork.

6.3.1.5 Ductwork Pressure and Velocity

Table 6-3 provides pressure classification and maximum air velocities for all ductwork.

Table 6-3: Ductwork Classification

Static Pressure	Maximum Air Velocity	Duct Classification
1 in WC	< 2000 fpm DN	Low Pressure
2 in WC	< 2000 fpm DN	Low Pressure
3 in WC	< 2500 fpm DN	Medium Pressure
4 in WC	< 2000 fpm UP	Medium Pressure
6 in WC	< 2000 fpm UP	Medium Pressure
10 in WC	> 2000 fpm UP	High Pressure

in WC – inches of water; fpm – feet per minute; DN – downdraft; UP – updraft

The duct network shall be pressure-tested after installation. The acceptable maximum leakage rate will be the applicable SMACNA standard.

When specifying air velocity, the designer shall consider the recommended duct velocities in Table 6-4, wherever noise generation could be a controlling factor. Primary air ductwork (fan connections, risers, main distribution ducts) shall be Medium Pressure classification, at a minimum. Secondary air ductwork (run-outs/branches from mains to terminals and distribution devices) shall be Low Pressure classification, at a minimum.

Table 6-4: Recommended Maximum Air Velocities in Ducts to Control Noise

Application	Allowable Main Duct Velocities (fpm)
Private Offices, Conference Rooms, Libraries	< 1,200
Auditoriums	< 800
General Offices	< 1,500
Cafeterias	< 1,800
Laboratories	< (1,000 – 2000)

fpm – feet per minute

Pressure losses in ductwork shall be designed to comply with the criteria stated above. This can generally be accomplished by using smooth transitions and elbows with a radius of at least 1.5 times the radius of the duct. Where mitered elbows must be used, double-foil, sound-attenuating turning vanes shall be provided. Mitered elbows are not permitted where duct velocities exceed 2,000 fpm.

6.3.1.6 Ductwork Sizing

Supply and return ductwork shall be sized using the equal friction method, except for ductwork upstream from variable air volume (VAV) system terminals. Duct systems designed using the equal friction method generally allow for sufficient static pressure capacity in the supply and return fans to compensate for deficiencies in field installation and future changes to the system layout. In buildings with large areas of open plan space, the main duct shall be oversized to allow for future expansion. Air flow diversity shall also be a sizing criterion—a maximum of 80 percent diversity (90 percent for laboratory spaces, in accordance with Labs21) shall be assumed at the AHU(s) and decreased the farther the ductwork is from the source, until air flow diversity is reduced to zero for the final portion of the system. For laboratory systems that are sized based on fume hood exhaust control, a maximum diversity of 98 percent (per Labs21) shall be assumed.

6.3.1.7 Access Panels

All ductwork shall have an access panel that provides access to each operating part, including:

- Splitter dampers
- Manual volume dampers
- Motorized volume dampers
- Fire dampers
- Smoke dampers.

6.3.1.8 Air Delivery Devices

Terminal ceiling diffusers or booted-plenum slots shall be specifically designed for VAV air distribution, where applicable. Booted plenum slots shall not exceed 4 feet in length, unless more than one source of supply is provided. “Dumping” action at reduced air volume and sound power levels at maximum delivery shall be minimized. For VAV systems, the diffuser spacing selection shall not be based on the maximum or design air volumes, but rather on the air volume range that the system is expected to operate within the majority of the time. The designer shall consider the expected variation in range of the outlet air volumes, to ensure that the air diffusion performance index (ADPI) values remain above the specified minimum for the project. This is achieved by minimizing temperature variation, ensuring effective air mixing between supply and return air streams, and preventing objectionable drafts in the occupied space (drafts typically occur in the space from 6 inches to 6 feet above the floor).

6.3.1.9 Plenum and Ducted Return Air Distribution

With a return plenum, care must be taken to ensure that the air drawn through the most remote register actually reaches the AHU. The horizontal distance from the farthest point in the plenum to a return duct shall not exceed 50 feet. The maximum airflow that is collected by any single return grille shall not exceed 2,000 cubic feet per minute (cfm). Return air plenums shall be sealed air-tight with respect to the exterior wall and roof slab or ceiling deck, to avoid creating negative air pressure in exterior wall cavities that would allow intrusion of untreated outdoor air. All central, multi-floor type return air risers must be ducted.

Other, less-flexible building spaces, such as circulation, public spaces, and support spaces, shall have ducted returns. Where fully-ducted return systems are used, the project HVAC engineer shall consider placing returns close to floor level so as to work in complement with fresh air supplied near the ceiling (except in an underfloor air distribution [UFAD] system—refer to Section 6.3.11). Return air ducts in the ceiling plenum of the floor below the roof shall be insulated. Sound attenuation shall also be provided on the return ductwork, as required to minimize noise and vibration.

6.3.1.10 Special Applications

Ductwork shall also meet the following requirements, where pertinent:

- The minimum rectangular duct size shall be 6 inches by 6 inches cross-section, and the minimum round duct size shall be 4 inches diameter cross-section, unless otherwise approved by EPA. Round ducts shall be installed wherever feasible, due to generally reduced noise, pressure loss, and leakage compared with rectangular ducts.

- Low-velocity ducts shall be sized to between 0.05 in WC per 100 linear feet (LF) and 0.08 in WC per 100 LF of ductwork, where possible.

- For large duct systems, the designer shall perform iterative calculations and optimize design parameters, as necessary, to ensure that selected system/configuration is the lowest life cycle cost alternative that meets the project requirements.

- Ductwork shall be designed to comply with NFPA 90A. This includes installation of smoke and fire dampers at fire-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.

- Ductwork that handles moisture-laden air exhausted from areas such as shower rooms, dishwashing areas, laboratory glassware preparation areas, and other areas where condensation may occur on the duct interior shall:

    - Be of aluminum construction

    - Have welded joints and seams; and

    - Provide outlets/penetrations for collecting condensate 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 axial configuration of the barrier penetration shall be considered during design of the penetration delay. Detailed requirements for security barriers are to be determined after consultation with the EPA project manager.

- Do not install underground ductwork because of potential health risks associated with soil-incorporated termiticides (e.g., chlordane) and/or potential radon gas in the soil. In addition, the following types of ductwork construction are prohibited:

    - Sub-slab or intra-slab HVAC system ducts

    - Plenum-type, sub-floor HVAC systems, as defined in the Federal Housing Administration (FHA) minimum acceptable construction criteria guidance (*under-*

floor, non-plenum duct networks are allowed and encouraged where occupant comfort, energy savings, and/or reduced "churn" costs would result)

- HVAC ducts in contact with the ground within an enclosed crawl space

- Other HVAC systems where any part of the ducting is in contact with the ground.

- Installation of plenums above laboratory spaces is prohibited.

- Manual volume dampers shall be provided at each branch take-off from the main supply, return, and exhaust ducts serving two or more air devices. Example specifications for manual dampers are contained in the Unified Facilities Guide Specifications (UFGS), Section 23 00 00, sub-sections 2.10.4 and 2.10.5 (www.wbdg.org/ccb/).

6.3.1.11 Steam Humidifier Wands

Access doors shall be provided to enable maintenance personnel to inspect and service steam humidifier wands in ductwork. For more specifications on humidification systems, refer to Section 6.3.6 below.

6.3.2 Air Handling Units (AHUs)

6.3.2.1 AHU Sizing and Selection

In order to size and select appropriate AHU(s) for the application, air distribution systems should be sized:

- For at least 25 percent future expansion in fume hoods and total fume hood exhaust volumes (laboratory facilities), so long as project-specific energy efficiency targets for the AHUs across the expected range of operating conditions are achieved

- For increases in non-fume hood ventilated equipment (e.g., kitchen equipment, laboratory furnaces); and

- To accommodate known or anticipated future upgrades.

Zone loads must be calculated accurately to avoid excessive throttling of airflow due to oversized fans and terminal units. To reduce potential handling of excess, unnecessary air volumes, the ventilation system design shall only include high-entrainment type diffusers (3:1 minimum), such that air velocity is maximized even at low airflow rates.

The maximum capacity of any AHU (including dedicated outdoor air [DOA] ventilation units, dedicated perimeter pressurization units, floor-by-floor AHUs, and AHUs serving special areas) shall not exceed 25,000 cfm. Smaller, modular units are encouraged to facilitate flexible zone control, particularly for spaces that involve high swing load operating conditions. Examples of such facilities include those with a second shift much smaller than the daytime shift and laboratories that frequently alter (e.g., upsize/downsize) operations in response to changing research requirements.

AHUs are confined spaces per OSHA regulations (29 CFR 1910.146). Special safety precautions are therefore necessary before personnel attempt to access an AHU for inspection or servicing. All access doors to AHUs shall be labeled, "Confined Space—Do Not Enter Without Proper Permits and Safety Procedures." Access doors shall comply with applicable NFPA standards, IBC, or local fire codes if more stringent. Refer to Volume 3 of this Manual for additional safety requirements associated with confined space entries.

6.3.2.2 Temperature and Humidity Control

Psychrometric process charts shall be prepared for each AHU application, characterizing full- and part-load operating conditions. AHU coil sizing and design shall ensure that conditioned space temperatures and humidity levels are maintained within the acceptable range, per facility-specific requirements and ASHRAE Standard 62.1 (refer also to Section 6.3.6), or in the case of laboratory work spaces, the applicable guidance developed by the Labs21 program (refer to Section 6.3). Direct reheat and/or humidification shall be provided only where required to meet design space conditioning requirements.

6.3.2.3 Setback Mechanism

The setback mechanism shall provide a low-speed operational setting for AHU fan motors in a particular zone. Fan motors can be simultaneously activated. The setback mechanism shall be designed to nominally provide:

- A minimum flow that satisfies indoor air quality requirements
- Heating season (winter) zone temperatures no less than 55°F
- Cooling season (summer) zone temperatures no greater than 85°F.

The HVAC system(s) nighttime setback shall be controlled by a timer connected to the building automation system (BAS) (refer to Chapter 8 of this Manual).

6.3.2.4 Noise Levels

All air handling systems and equipment (e.g., fans, terminal units, AHUs) shall be provided with vibration isolators and flexible ductwork connectors to minimize transmission of vibration and noise. Systems shall satisfy the noise criteria recommended for various types of spaces and the vibration criteria listed in the ASHRAE handbooks (e.g., Chapter 7 of the ASHRAE *Handbook—Fundamentals*). The combined noise level generated by mechanical and electrical building equipment shall not exceed 70 decibels (dBa) in mechanical rooms or 55 dBa elsewhere. Where air handling equipment and air distribution systems cannot meet these requirements, sound- and vibration-attenuation devices shall be installed.

6.3.2.5 AHU Condensate

Reuse of condensate from AHUs (and the entire air handling system) shall be considered, particularly in geographic locations with extended periods of warm, humid climatic conditions. In applications where AHU condensate reuse is life cycle cost-effective, it should be implemented. Condensate recovery is discussed in greater detail in Section 6.6.6.

6.3.2.6 Coils

Heating and cooling coils shall comply with ARI 410. Heating and cooling coil selection shall also comply with the guidelines in the ASHRAE *Handbook—Fundamentals* and the ASHRAE *Handbook—HVAC Systems and Equipment*. Coil manufacturers shall self-certify coil performance in accordance with ACRI requirements, or provide written certification from a nationally-recognized, independent testing firm. Additional requirements for heating and cooling coils are as follows:

- Heating and cooling coils shall be composed of materials appropriate for the corrosive atmosphere in which they operate. In non-corrosive environments, all hot water heating and chilled water cooling coils shall be copper tube and copper-finned materials

- Heating coils shall be designed for a maximum face velocity of 750 fpm
- Cooling coils shall be designed for a maximum face velocity of 550 fpm. Coils designed with face velocities exceeding 500 fpm shall have features that prevent condensate carry-over, or else use moisture eliminators
- All coils shall have a drain for collection of condensate
- Re-circulating air systems designed for outdoor 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 heating and cooling coils. If the theoretical mixed air temperature is calculated to be above 35°F, 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 the discharge air temperature without modulation of the 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*)
- Individual finned tube coils shall generally be between six and eight rows with at least 12 fins per inch, to ensure that the coils can be effectively and efficiently cleaned
- Dehumidifying coils shall be selected for no more than negligible water droplet carryover beyond the drain pan at design conditions. Equipment and other obstructions in the air stream shall be located sufficiently downstream of the coil so that it will not come in contact with any minimal water droplet carryover.

6.3.2.7 Drains and Drain Pans

Drain pans shall be fabricated from stainless steel, insulated, and adequately sloped and trapped to ensure drainage. Drains in draw-through configurations shall have traps with a depth and height differential between inlet and outlet equal to the design static pressure plus 1 inch, minimum.

6.3.2.8 Filter Sections

Filters shall be sized for a maximum face velocity of 500 fpm. Filter media shall be fabricated such that fibrous shedding does not exceed levels specified in ASHRAE 52.2. The filter housing and all air-handling components downstream shall not be internally-lined with fibrous insulation. Double-wall construction or an externally insulated sheet metal housing is acceptable. The filter change-out pressure drop, <u>not</u> the initial clean filter rating, must be used in determining fan pressure requirements. Differential pressure gauges and sensors shall be placed across each filter bank to allow rapid and accurate assessment of filter dust loading, as reflected by air pressure drop across the filter. All such sensors shall be connected to, and transfer real-time readings to, the BAS.

6.3.2.9 Ultraviolet Light, "C" Band Emitters/Lamps

Ultraviolet light, "C" band (UVC) emitters/lamps shall be installed in each AHU, downstream of all cooling coils and above all drain pans to prevent/control airborne and surface microbial growth and transfer. The emitters/lamps used must be specifically manufactured for this purpose. Safety interlocks/features shall be provided to limit potential hazards to maintenance staff.

6.3.2.10 Access Doors

Access doors shall be provided for each AHU at the following locations:

- Downstream of each coil
- Upstream of each filter section
- Adjacent to each drain pan and fan section
- Adjacent to the motor, drive, and bearing section(s) of the AHU.

Access doors shall be of sufficient size to allow personnel to access the unit to inspect and service all components.

6.3.2.11 Terminals

VAV terminals shall be certified under the ARI Standard 880 Certification Program and shall carry the ARI Seal. If fan-powered, the terminals shall be designed, built, and tested as a single unit, including the motor and fan assembly, primary air damper assembly, and any accessories. VAV terminals shall be pressure-independent type units. Air leakage from the casing of each individual VAV box/terminal shall not exceed 2 percent of its rated capacity. Units shall have self-contained controls that are compatible with the BAS as described in Chapter 8 of this Manual (i.e., BACnet, LonWorks, or equivalent). Refer to Sections 6.3.3 and 6.3.9 for additional requirements for VAV systems.

Fan-powered terminals shall be equipped with ducted returns, featuring a filter/filter rack assembly with the filters having a Minimum Efficiency Reporting Value (MERV) of 10 (60 percent to 65 percent efficient with a maximum allowable particle size of 1.0 micron). The return duct shall be covered on all externally-exposed sides with a minimum of two inches of insulation. Fan-powered terminals shall have electronically commutated motors (ECM) for speed control to allow continuous fan speed adjustment from maximum to minimum, as a means of setting/adjusting the fan airflow. Units shall have self-contained controls that are compatible with the BAS as described in Chapter 8 of this Manual.

The return plenum box for fan-powered terminals shall be a minimum of 24 inches in length and shall be double-walled (with insulation in-between) or contain at least one elbow, where space allows. Fan-powered terminals may have hot water heating coils used for maintaining temperature conditions in the space under partial load conditions. However, fan-powered terminals located in proximity to the perimeter zones and on the top floor of the building shall always contain hot water coils for heating.

6.3.3 Fans

Fans shall be designed and specified to ensure stable, non-pulsing, and aerodynamic operation in the design 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 the fan. Fans with motors of greater than 20 hp shall use fixed (non-adjustable) drives that can be adjusted by using fixed motor pulley sheaves of different diameters. Supply AHUs and return air fans in VAV systems shall control capacity through the use of variable-frequency drives (VFDs). All fans shall comply with the following:

- ANSI/AMCA Standard 210
- ASHRAE, *Handbook—HVACR Systems and Equipment*
- ACGIH, *Industrial Ventilation*.

Fans shall be located within the ductwork system, in accordance with the requirements of AMCA 201. Motors shall be sized according to properly calculated brake horsepower (bhp) fan requirements (*do not specify "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, structural integrity/fatigue resistance over the required performance period, and cost.

Spark-resistant construction shall be used where required by NFPA Standards. All fans and accessories shall be designed and specified to meet all requirements of NFPA 255, regarding controlling spread of smoke and flame. Smoke detectors for automatic control in air distribution systems shall be located in accordance with the requirements of NFPA 90A, Chapter 4.

6.3.3.1 Supply, Return, and Relief Air Fans

All fans shall bear the AMCA seal, and performance tests shall be conducted in accordance with AMCA 210. Fans shall be selected on the basis of required horsepower, as well as sound power level ratings at full-load and at part-load conditions. Fan motors shall be sized so they do not run at overload anywhere on their operating curve. Fan operating characteristics must be checked for the entire range of flow conditions, particularly for forward-curved fans. Fan drives shall be selected based on a service factor of 1.5, and fan shafts shall be selected to operate below the first critical speed. Horizontal discharge fans operating at high static pressure shall include thrust arrestors.

6.3.3.2 VAV System Fans

Centrifugal, double-width, double-inlet, forward-curved, and airfoil fans are preferred for VAV AHUs. The minimum volume setting of the VAV fans shall equal the largest of the following:

- 30 percent of the peak supply volume
- 0.4 cubic feet per minute per square foot (cfm/ft^2) of conditioned zone area
- The minimum outdoor airflow to satisfy ASHRAE Standard 62.1 ventilation requirements.

VAV supply fan(s) shall be capable of operating at the following three design conditions, without significant noise or vibration and without overloading:

- Normal peak load (including diversity)
- Maximum cooling load (no diversity and with terminal box dampers open)
- Minimum cooling load (with terminal boxes at the minimum flow condition).

VFD motors and fan drives shall only be used in conjunction with VAV ventilation systems.

Additional specifications for VAVs that are installed in laboratory settings are contained in Section 6.3.9. Sensing and control of VAV ventilation systems is covered in Section 8.3.3.

6.3.3.3 Setback Mechanism

Refer to Section 6.3.2 for setback mechanism requirements.

6.3.4 Exhaust Air Energy Recovery

Exhaust air heat recovery systems that involve direct air exchange (e.g., enthalpy wheels) shall be considered for use at all facilities except where return air from the conditioned space contains either high concentrations of airborne contaminants or exhausts from food preparation areas. Exhaust air heat recovery systems shall operate at a minimum of 70 percent efficiency. The heat recovery systems must be capable of connecting to a microprocessor controller that in turn can be connected to the BAS (see Chapter 8 of this Manual). Pre-filters (i.e., upstream of the heat recovery equipment) shall be provided in all heat recovery systems.

With the air exhaust heat recovery system in the heating mode, heat from exhaust air is recovered and used to preheat the outdoor air supply, domestic hot water, boiler combustion air, and/or boiler makeup water. In the cooling mode, exhaust air is used to pre-cool the outdoor air supply. In addition to the cost savings from energy conservation, total system pressure is increased, thus potentially reducing fan size requirements and fan power consumption. Six methods available for exhaust air heat recovery air are discussed as follows:

- Rotary air wheels (enthalpy wheels)
- Stationary heat exchangers
- Heat pipes
- Run-around systems (closed loop and open loop)
- Heat recovery from light fixtures
- Air-to-water heat pumps.

Achievement of the minimum Energy Performance Prerequisite and/or obtaining points under the Energy Performance Credit can be aided by use of exhaust air energy recovery devices (e.g., enthalpy wheels). However, in some situations (e.g., at laboratories), these devices can potentially transfer contaminated air back into the space, thus impairing the facility's ability to meet the LEED-NC 2009 Indoor Environmental Quality (IEQ) Prerequisite and/or obtain points under IEQ Performance Credits. In those situations, heat pipes or other non-contact energy recovery devices may need to be specified if energy recovery is pursued.

The rotary air wheel and heat pipe methods require that supply and exhaust ducts be adjacent to each other. Rotary air wheels will always result in some mixing of the exhaust and supply airstreams. When selecting heat recovery systems, re-entrainment and cross-contamination of air streams must be considered and eliminated. For more information, refer to the ASHRAE *Handbook—HVAC Systems and Equipment*, Chapter 25, "Air-to-Air Energy Recovery Equipment." Brief descriptions of each method follow:

6.3.4.1 Rotary Air Wheel Method

Rotary air wheels (also often called "enthalpy wheels") operate by transferring heat using a finned wheel, which rotates between the exhaust and supply duct. There are two types of rotary air wheels—one transfers only sensible heat, the other transfers both sensible and latent heat. The total heat transfer effectiveness of rotary air wheels generally ranges from 50 percent to 85 percent for equal supply and exhaust mass flow rates (usually slightly less due to air leakage). This technology should be considered for HVAC systems where the exhaust airflow is 4,000 cfm or greater.

6.3.4.2 Plate Heat Exchanger Method

In the plate heat exchanger method, heat is transferred across alternate passages carrying exhaust and supply air. The passages (e.g., a tube bundle in an open shell) can be configured in a counter-flow or cross-flow pattern. Plate heat exchangers are generally 40 percent to 80 percent efficient at recovering heat energy; the efficiency depends on the system design, temperature differential between the air streams, and air stream mass flow rates. Cross-flow methods require less space, but counter-flow methods tend to be more efficient in this application. With the plate exchanger method, only sensible heat is transferred.

A plate heat exchanger is a static device (i.e., no moving parts), and the only regular maintenance required is occasional cleaning of the inner and outer surfaces of the tubes. In addition, because the two air streams are kept separate, there is little or no probability of cross-contamination and less air leakage than a rotary air wheel.

6.3.4.3 Heat Pipe Method

The heat pipe method involves a self-contained, closed system that transfers sensible heat, thus pre-heating or pre-cooling the intake air stream (as applicable). A heat pipe system consists of bundles of finned copper tubes, similar to cooling coils, sealed at each end and filled with a wick and the working fluid. For the most efficient system, the exhaust and supply air are oriented in a counter-flow configuration. For cooling season operations, the system transfers heat from the incoming air stream (thus pre-cooling it) and rejects the heat into the AHU discharge stream (i.e., back to the ambient atmosphere outside the building). For heating season operations, the system transfers heat to the incoming air stream from the conditioned space, thus pre-heating it.

The performance of heat pipe systems can be improved by sloping the heat pipe such that the “warm” side is lower than the “cool” side. Heat pipe systems shall be equipped with solenoid valve controls, to enable operation under part-load conditions.

6.3.4.4 Run-around System Method

In this method, there are two configurations: closed loop and open loop. Closed loop method run-around systems transfer sensible heat between the air streams using two coils (one in the supply system and one in the exhaust system) filled with water, glycol, or other working fluid. The working fluid is circulated through the closed pipe loop using a dedicated pump. This method can be expected to increase the outdoor air temperature by up to 65 percent of the outdoor air/exhaust air temperature difference. If the winter design temperature is 32°F or below, this system requires an antifreeze solution.

The open loop method transfers both sensible heat and latent heat. This is an air-to-liquid/liquid-to-air enthalpy recovery system, in which the working fluid flows into each cell with the aid of a pump, in a manner similar to cooling tower flow. Sorbent liquid used with this system can be bacterio-static, if necessary.[11] The open loop method shall not be used for high-temperature applications.

6.3.4.5 Heat Recovery from Light Fixtures

The sensible heat emitted by lighting fixtures and lamps is a large portion of most facilities’ total cooling load. Recovery of this heat reduces energy usage both by reducing the room cooling load and by recovering usable heat energy. There are several different variations of this method; however, all use fans to circulate air through light troffers and fixtures, thus capturing excess heat and cooling the fixtures in the process. There are several restrictions and requirements that must be observed:

- The minimum required ventilation rate to the space must be maintained, even where no longer required for space conditioning (due to the efficiency gains).

[11] A bacteriostatic solution limits the growth of bacteria by interfering with protein production, deoxyribonucleic acid [DNA] replication, or other aspects of bacterial cellular metabolism).

- This method should not be used with VAV systems.
- This method should not be used for “clean” rooms; animal laboratories; or laboratories handling toxic, explosive, or bacteriological substances.

An additional advantage of this method often is increased ballast and lamp life, due to reductions in luminaire surface temperatures.

6.3.4.6 Heat Pump Water Heaters

Rooms containing laundries and food preparation facilities are often extremely hot and uncomfortable for staff. Heat from the indoor spaces of these rooms can be captured for heating domestic water by using a dedicated heat pump that mechanically concentrates the diffuse heat contained in the ambient air. The most favorable applications for heat pump water heaters (HPWH) have some or all of the following characteristics:

- The need for both hot water and space cooling and dehumidification is large and regular, such as in a laundry or kitchen.
- Energy costs for heating hot water (e.g., electricity, natural gas) are high.
- There is a need for continual mechanical ventilation, such as for humidity/moisture control or to maintain acceptable IAQ.

HPWHs with capacities up to 27 tons of refrigeration (ton R) are commercially available. In addition, HPWHs are often feasible and cost-effective as pre-heaters (i.e., heat water to an interim temperature, which is then raised by additional electric resistance, gas, solar, or other mode of heating to its final temperature). Depending on the state in which the facility is located, utility rebates and other financial incentives also may be available for installing HPWHs. These should be fully evaluated and utilized to the extent possible, to maximize life cycle return on investment (ROI).

6.3.5 Thermal Energy Storage

Thermal energy storage (TES) involves the capture and storage of energy produced during off-peak hours for later use during peak demand times. The most common application is to produce ice or chilled water during off-peak hours, when summer electricity demand charges are lowest, for subsequent use during daylight, peak hours. In some cases, a large ice bath is produced; in others, the ice is allowed to form on tubes of water that contain the transfer fluid (known as the “ice on coil” method). Thermal storage systems commonly use one of three thermal storage media: water, eutectic salts, or ice. The approximate volumes of each media required for storage of 1 ton R-hour of cooling are approximately 11.4 cubic feet (ft^3), 2.5 ft^3, and 1.5 ft^3, respectively.

TES should generally be considered in situations where this technology could:

- Reduce peak power demand charges
- Provide additional cooling capacity (in lieu of adding more cooling equipment)
- Provide redundancy to ensure reliability of cooling to critical applications (e.g., large data centers).

In order for TES to be effective, the storage reservoir shall be capable of supplying the design chilled water temperature during the final operating hour of each cycle (i.e., after maximize heat loss from the reservoir has occurred and prior to recharging).

Storage tanks or reservoirs used for TES shall be prefabricated to applicable code requirements. The tank shall be insulated, and its capacity and performance (as well as of any piping systems such as glycol circulation pipes) shall be guaranteed by the vendor. The system shall have self-contained direct digital controls (DDC) that are linked with the BAS and that control/optimize charging and discharging sequences.

6.3.6 Humidification and Dehumidification

6.3.6.1 Humidification

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 by project-specific criteria. Humidification shall be limited to building areas requiring special conditions. General office space shall not be humidified unless severe winter conditions are likely to cause indoor relative humidity to fall below 30 percent. Where humidification is necessary, atomized hot water, clean steam, or ultrasound may be used and shall be generated by electronic or steam-to-steam generators.

Because interior relative humidity levels are closely linked to thermal comfort, EPA facilities that undertake effective dehumidification measures (e.g., dessicant air dryers, slip-stream cooling) may be better positioned to qualify for points under the IEQ Thermal Comfort Credits.

To avoid the potential for over-saturation and condensation at low load, the total humidification load shall be divided between multiple, independently modulated units (single-unit humidifiers shall not be used). Where process steam is required during summer seasons for humidification or sterilization, a separate “clean steam” generator shall be provided and sized for the total load, including the seasonal component. Humidifiers shall be centered on the air stream to prevent vertical stratification of the moist air. All associated equipment and piping shall be stainless steel. Humidification systems shall have microprocessor controls and the capability to connect to the BAS.

Make-up water for direct evaporation humidifiers, direct evaporative coolers, or other water spray systems shall originate directly from a water source that meets potable water quality standards (or better), with respect to both chemical and microbial contaminants. Humidifiers shall be designed so that microbiocidal chemicals and water treatment additives are not emitted into the ventilation air stream. Air washer systems are not permitted for cooling.

6.3.6.2 Dehumidification

Dehumidifiers shall be installed in spaces or zones where the sustained relative humidity is anticipated to be 50 percent or greater. In addition, dehumifiers shall be equipped to shut off when the space/zone relative humidity (as indicated by humidity sensors) remains below 50 percent for greater than five minutes. For high-occupancy applications, solid desiccant with silica gel may be used in combination with mechanical cooling (i.e., coils, rotary air wheels, heat exchangers).

Desiccant cooling units shall be equipped with airflow-setting devices for both process and reactivation air flows, and shall be equipped with gauges or digital displays to report those air flows continuously. Natural gas or condenser waste heat shall be used as fuel for reactivation of the desiccant. Lithium chloride liquid desiccants are not permitted.

6.3.7 Fire and Smoke Dampers

Fire and smoke dampers shall be provided in accordance with the most recent editions of the following standards and guidelines:

- NFPA 90A
- IBC (and applicable local codes if more stringent than IBC),
- UL 555, *Standard for Fire Dampers*
- UL 555S, *Smoke Dampers*
- The ASHRAE *Equipment* Handbook, Chapter 16
- The ASHRAE *Fundamentals* Handbook, Chapter 32
- SMACNA Standard, *HVAC Duct Construction Standards, Metal and Flexible.*

Fire dampers shall be provided at firewall barriers, and shall provide damper and mounting fire resistance that equals or exceeds the fire resistance of the construction in which installed. These include a 1.5-hour (for use in barriers with less than 3-hour rating) or 3-hour fire resistance rating, as applicable, and dynamic closure against a heated airflow velocity of at least 2,000 fpm under pressure of 4 inches of water, unless the damper is classified for a static “fans off” system. Fire dampers may be accordion-type with a fusible link or rotating louvers with electro-mechanical controls, as dictated by the application. Fusible links shall melt at not less than 160°F or at other temperature, per applicable codes and standards.

Fire dampers assemblies shall be completed with required perimeter mounting angles, sleeves, breakaway duct connections, corrosion-resistant springs (as applicable), bearings, bushings, and hinges. Where ducts pass through partitions, the penetration surrounding the duct shall be sealed with a non-combustible material. Unless tested and approved for this configuration, the area between the fire damper and the fire damper sleeve shall not be filled with any type of material. This space allows for thermal expansion of the damper assembly under fire conditions.

The dampers shall be labeled in accordance with UL 555. Wall collars also shall be constructed in accordance with UL 555. Fire dampers shall be tested upon installation in accordance with UL 555. Combination fire and smoke dampers shall be labeled, installed, and tested in accordance with UL 555S.

Additional requirements for facility fire protection systems are contained in Chapter 9 of this Manual.

6.3.8 Demand-Controlled Ventilation (DCV) and Carbon Dioxide (CO_2) Monitoring Equipment

DCV should be provided in high occupancy zones (e.g., large conference rooms) and remote ventilation zones (e.g., storage rooms). The DCV system shall be integrated with the BAS and include CO_2 sensors for interior (between 3 feet and 6 feet above the floor) and exterior measurements. Laboratory facilities shall not be equipped with DCV in any spaces (including support spaces) without EPA’s specific approval.

Section 6.1.3.4 of ASHRAE Standard 62.1 addresses the issue of intermittent or variable occupancy. This section allows the adjustment of ventilation for variable occupancy, provided that ventilation needs are met at all times. When contaminants do not present short-term health hazards and are dissipated during subsequent unoccupied periods, initiation of the outdoor fresh air supply may be designed to lag occupancy. A committee of design professionals has provided interpretations to the requirements of the ASHRAE standard, which include many examples of how DCV can be acceptably implemented and under which conditions.

DCV systems generally should be sized based on the peak occupancy of the space or zone and allow ventilation rates to vary, depending on occupancy. This will maximize energy savings while also ensuring that spaces can be rapidly purged (and required air quality levels restored) upon resumption of occupancy. Ventilation systems that are downsized based on less than 100 percent diversity may not be capable of purging all required zones quickly enough and thus are not recommended in DCV applications. *(Systems with air-side economizers already have the capability to rapidly introduce outdoor air into the HVAC system and thus could potentially be downsized—evaluate on a case-by-case basis).*

Contaminants should be controlled at the source in such a manner that the following indicator levels for carbon monoxide (CO), CO_2, and formaldehyde (HCHO) are not exceeded:

- CO – 2 parts per million (ppm), 8-hour time weighted average (TWA)
- CO_2 – 1,000 ppm, TWA (maximum); 850 ppm TWA (recommended)
- HCHO – 0.05 ppm, TWA.

EPA facilities can earn one point toward LEED-NC 2009 certification for installing a permanent monitoring system for CO_2 and airflow. The monitoring equipment must be linked with alarms that activate when a measurement outside a ±10% range of the nominal value occurs.

The DCV system shall regulate outside air ventilation such that, in office facilities, occupied space CO_2 is maintained to no more than 650 ppm above outside air conditions. CO and pressure differential monitoring shall be connected with the BAS for all spaces adjacent to (above, below, or to the side of) automobile, truck, or other source of combustion byproducts idling. (*Idling should be discouraged by the facility operators*).

6.3.9 Laboratory Ventilation Systems

6.3.9.1 Goals

Occupant health and safety shall be the primary and overriding goal of all laboratory ventilation systems. Therefore, laboratory ventilation systems must function effectively in conjunction with all fume hoods and associated exhaust systems (refer to Section 6.3.10). Maintaining comfortable interior temperature and humidity levels (to the extent possible given variation in occupant preferences) is also a critical goal for ventilation system design.

6.3.9.2 General Requirements

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 DOA ventilation systems (DOASs), with the exhaust directed through fume hoods (where fume hoods are present). Under no circumstances will the air supplied to any laboratory space be re-circulated to any other space.

The project HVAC engineer shall assume that HVAC systems at EPA laboratories must be continuously operational (i.e., 24 hours a day, seven days a week, summer and winter).

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. The levels of pressurization shall be project-specific and shall be determined in accordance with the following Labs21 publications: (1) *System Static Pressure Optimization*, Technical Bulletin, February 3, 2007; and (2) *Low-Pressure Drop HVACR Design for Laboratories*, Best Practices Guide, DOE/GO-102005-2042, February 2005.

Certain areas (e.g., at or in proximity to fume hoods) may require emergency manual override controls, which increase fresh supply airflow and simultaneously increase negative pressurization. The HVAC system that serves the particular laboratory area(s) shall be capable of managing the increased airflow during emergency override conditions. If the exhaust airflow will exceed the ventilation rate when the emergency override mode is in effect, a delay period of 30 to 60 seconds (or other suitable) after triggering the evacuation alarm shall be programmed into the system. This will aid occupants in evacuating the space before the doors become too difficult to open.

6.3.9.3 Design Guidelines

As discussed in the Labs21 *Best Practice Guide: Optimizing Laboratory Ventilation Rates*, September 2008, it is preferable to optimize the laboratory ventilation rates based on room geometry, research activities, occupancy schedules, and other parameters (as opposed to using a fixed number of air charges per hour [ACH] or fixed volume flow (i.e., CFM/ft^2). This position has been endorsed by numerous governmental and technical advisory bodies, including the American National Standards Institute (ANSI), the American Industrial Hygiene Association (AIHA), and the American Conference of Governmental Industrial Hygienists (ACGIH). However, for planning and preliminary design purposes, the following design goals may be assumed:

- Peak volumetric airflow equivalent to 8 ACH
- Nominal operating volumetric airflow equivalent to 6 ACH while the space is occupied
- Setback volumetric airflow equivalent to 4 ACH while the space is unoccupied.

(The peak airflow guideline of 8 ACH may be reduced if sufficient fume removal capability is demonstrated at lower ACH, for the type and quantity of a realistic chemical spill inside the laboratory module, to ensure occupant safety and health while the space is being evacuated and sealed off).

As outlined in the Best Practices Guide, key considerations for design of laboratory ventilation systems including the following:

- All relevant provisions of the IBC, as well as Federal, state, or local regulations and codes that are more stringent than the guidelines and requirements referenced herein must be followed. Where such codes are judged outdated or unduly restrictive, a variance should be sought from the applicable agency
- Excessive ventilation rates must be avoided, because they can result in increased concentrations of airborne contaminants by increasing the quantities partitioned into the air and subsequent dispersion within the room
- The mixing properties of any contaminants of concern that might be inadvertently spilled or released within the laboratory space should be evaluated. CFD modeling will be EPA's preferred approach in most situations to assess the time-dependent dispersal of contaminants. Instantaneous concentrations generated by the model shall be compared

with applicable OSHA or ACGIH health-based standards (e.g., permissible exposure limits [PELs], threshold limit values [TLVs]) and action levels (IDLHs)

- The decision pathway should follow the process illustrated on Figure 2, "Process Flowchart" of the Best Practices Guide

- Hazardous chemical "control banding" may be utilized to ensure that operations are segregated or grouped for the purpose of utilizing the minimum safe ventilation rates for each band. Control bands are determined by a chemical's: (1) relative toxicity; (2) quantities used/"scale" of the process; and (3) tendency to become airborne under conditions likely to occur routinely at the laboratory. Control banding also can be used for selection of fume hoods (refer to Section 6.3.10) and to determine which processes require even greater isolation (e.g., glove boxes)[12]

> **EPA facilities can earn one point toward LEED-NC 2009 certification if, in spaces where hazardous chemicals and/or gases are stored, they maintain: (1) a specific minimum exhaust airflow; and (2) a negative pressure differential relative to the surrounding spaces. (*There are additional requirements***

- Rather than over-sizing the primary ventilation and exhaust systems, the design engineer shall include appropriate emergency override ventilation systems, as previously described

- Identifying all temperature control zones within each laboratory module (or laboratory wing), and provide sensors to control each zone

- Rebalancing the HVAC system and reset controls during commissioning to maintain proper air flows and temperatures

- Be prepared and configured to handle ultra-dilute reference samples of chemical agents for the U.S. Department of Homeland Security.[13]

6.3.9.4 Setback Mechanism

A setback mechanism shall be included, which provides a low-speed operations setting for the fan motors of AHUs (and fume hoods, where applicable), in a particular zone. Fan motors can be simultaneously activated. The setback mechanism shall be designed to provide, when the sash is fully closed, a minimum of 25 cfm/ft^2 of fume hood work surface and 4 ACH (lower ACH may be approved by the EPA project manager). The exhaust requirements of fume hoods and other exhaust devices, as well as the temperature and humidity requirements, shall override laboratory minimum ACH. The setback mechanism shall also provide room temperatures of approximately 55°F in the winter and approximately 85°F in the summer, unless otherwise specified. The HVAC system(s) nighttime setback shall be controlled by a timer connected to the BAS.

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[12] One example of control banding implementation in a laboratory setting is the Pfizer Pharmaceuticals, "Chemicals in the Workplace" Program. It defines five Occupational Exposure Bands (OEBs), in accordance with animal toxicities (no adverse effect levels), acute oral toxicity (AOT), irritation potential, sensitization potential, and mutagenicity. The approach is not completely formulaic, i.e., professional judgment may be used to up-rate or down-rate a chemical's OEB. In addition, Pfizer has defined five Exposure Control Practice (ECP) Bands that correspond to each OEB. The types of ECPs range from open with area HVAC-only controls to work practices controls to partial or full process containment for the most hazardous OEB.

[13] Ultra-dilute reference samples of chemical agents are samples used to validate the accuracy and precision of laboratory detection equipment at very low concentrations.

6.3.9.5 Chilled Beams

Use of chilled beams shall be considered in the following circumstances:

- Spaces with a high sensible heat load (e.g., climates with many days of low relative humidity)
- Spaces where it is advantageous to "decouple" the heating load from the ventilation airstream (i.e., to right-size the ventilation system and use ventilation almost completely for health and safety purposes)
- Locations where dew point temperatures are relatively low
- Facilities with existing or planned ground source heat pumps (GSHPs) (*while in cooling mode, the "facility" side of a GSHP water loop typically produces water temperatures close to the ideal operating temperature for chilled beams*)
- At facilities where waterside economizers or cooling towers can supply most of all of the required heat removal
- Facilities with limited space for installing HVAC equipment and ductwork
- Areas/facilities where noise is a concern.

The chilled beam/induction assembly shall include an air inlet plenum, water coil(s), mixing chamber, and mounting brackets. Chilled beam air channels and other components shall be constructed from either 20 gauge (minimum) steel or sheet aluminum. One-half (½)-inch thick, UL-181, *Factory-Made Air Ducts, Air Connectors, and Closure Systems*-approved insulation shall be applied to the exterior of the air inlet plenum, to prevent condensation from forming on the outside of the unit casing. A two-pipe or four-pipe water coil shall be provided, consisting of ½-inch copper tubes mechanically expanded into aluminum fins, all within a galvanized steel frame. The coils must be rated for a maximum operating pressure of at least 300 psig, and shall be burst-tested at 450 psig (air under water) and leak-tested at 300 psig.

Induction nozzles shall be provided, in the number and configuration recommended by the manufacturer. The chilled beam flow channel shall be connected to the feeder air duct using a straight or gentle-radius flexible duct in accordance with local codes. Flexible hose, where used, shall be Teflon® with stainless steel braiding, rated for a minimum of 300 psig, and with sweat or National Pipe Thread (NPT) threaded connections. The chilled beam assembly shall include an air-tight sampling port to permit static pressure measurements with a portable device (e.g., manometer) during TAB and commissioning activities.

6.3.10 Laboratory Fume Hoods

Laboratory fume hoods (hereinafter "fume hoods"), as constructed, as manufactured, as installed, and as used, shall conform to current EPA design, testing, safety, health, and environmental requirements. The Project HVAC Engineer, EPA Lead Chemist, On-Site Laboratory Manager(s), and other experts as necessary, shall be responsible for selecting fume hood types and sizes that are appropriate to the intended uses. The requirements of this subsection and Chapter 4 and Appendix XX of the Safety Manual shall be followed. Fume hoods shall be considered an integral part of the overall building HVAC system, and shall be included in TAB activities prior to building acceptance.

The following considerations shall be implemented during any design process that involves fume hood selection and installation:

- Identify any user-specific needs for fume hood 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 performance testing of potential fume hood and control system configurations in accordance with:
    - ANSI/ASHRAE 110; and
    - EPA's *Performance Requirements for Laboratory Fume Hoods—As Manufactured Performance Tests, As Installed Performance Tests, and As Used Performance Tests* (Appendix XX of the Safety Manual)
- Analyze expected laboratory space air flow dynamics to evaluate whether airflow tracking, active pressurization control, or a combination of both is required
- Properly select the location and type of room supply air diffusers
- Determine the failure mode of all terminal boxes to ensure that the laboratory pressurization criteria are met under all anticipated operating conditions
- Confirm that laboratory temperature control does not override the minimum fume hood ventilation requirements
- Analyze the effects of cross-draft velocities, room diffuser type(s), and diffuser location(s) when evaluating whether a particular fume hood(s) design configuration and operating parameters will ensure effective contaminant containment.[14]

In accordance with ANSI/AIHA Z9.5-2009, *Laboratory Ventilation—Draft Standard*, the flow rate of constant volume fume hoods and the minimum flow rate of VAV fume hoods shall be sufficient to prevent hazardous concentrations of contaminants within the fume hood. In addition to maintaining proper hood face velocity, fume hoods shall maintain a minimum exhaust volume to ensure that contaminants are properly diluted and exhausted from the fume hood. The project mechanical engineer may choose to increase the minimum fume hood flow rate if the ventilation equipment and the airflow control system cannot regulate room air rates at the values required to effectively pressurize the room.

As mentioned in Section 6.2.2, the use of CFD numerical models shall be considered to aid in modeling airflow and chemical concentrations in the vicinity of fume hoods and/or other areas within the laboratory module(s). Output from these models may produce significant benefits in "right-sizing" the ventilation and exhaust systems, with significant capital cost and annual energy cost savings that often justify the additional upfront costs associated with CFD modeling.

In accordance with ASHRAE 90.1-2007, Section 6.5.7.2 and EPA design guidelines, laboratories having exhaust rates from fume hood systems greater than 15,000 cfm and/or a 100 percent DOAS design flow rate of 4,000 cfm or greater shall include at least one of the following features:

[14] Smith, T.C. and N. Paschke, *Investigating Fume Hood Performance as a Function of Laboratory Air Supply*, Labs21 2007 Annual Conference, www.is2l.org/elibrary/smith2007.html.

- VAV hood exhaust and room supply system capable of reducing exhaust and makeup air volume to individual spaces by at least 50 percent of the design value(s) per ASHRAE and to the minimum air requirement per EPA guidelines;

- Direct makeup air supply that meets the following requirements:

  – Equal to at least 75 percent of the exhaust rate

  – Heated no warmer than 2°F below the room set point

  – Cooled to no lower than 3°F above the room set point

  – No humidification added; and

  – No simultaneous heating and cooling used for dehumidification control

- Energy recovery systems to precondition makeup air from fume hood exhausts in accordance with Section 6.5.6.1, *Exhaust Air Energy Recovery.* Energy recovery technologies that involve exchange of exhaust and supply air (e.g., enthalpy wheels) are not permitted, but other technologies (e.g., heat pipes or run-around loops) may be used.

The project HVAC engineer also shall consider using VFDs on fan motors, where cost-effective, to reduce the design flow rate below 4,000 cfm.

When performing energy simulation models to check for compliance with ASHRAE 90.1-2007 (or most recent version) for laboratories, the modeler shall utilize the occupancy, lighting, equipment, and fume hood diversity schedules contained in the *Laboratory Modeling Guidelines Using ASHRAE 90.1-2007, Appendix G*, prepared by Labs21 and dated August 27, 2008 (or most recent version).

6.3.10.1 Basic Fume Hood Requirements

EPA fume hoods shall have an ASHRAE performance rating, as manufactured, of 4.0 AM 0.05 (i.e., leakage rate $\leq$ 0.05 ppm at 4.0 liters per minute at the design sash opening). EPA requires that all fume hoods perform in compliance with EPA's, "As Installed" specifications (refer to Appendix XX of the Safety Manual) prior to acceptance and use. Unless otherwise directed by the EPA project manager, the construction contractor shall provide a third-party testing agent to certify the hoods' performance, with an EPA representative present to witness the test. A current list of approved low-velocity fume hoods (also called high performance fume hoods) and conventional fume hood models can be obtained from EPA SHEMD. Generally, it is EPA's preference that high performance fume hoods (e.g., those designed to operate in the range of 60 fpm, compared with conventional fume hoods, which operate at 80 – 100 fpm) be specified, where practicable.

Materials used in the construction of fume hoods and of associated exhaust blowers shall meet corrosion-resistance standards for the chemicals used and generated in the hood. Blowers shall be rated or otherwise approved for use by a recognized certifying body. Plumbing fixtures and electrical outlets must meet existing codes. In addition, all fume hoods shall meet the following requirements:

- Ceiling and wall diffusers for the distribution of supply air in the laboratory shall not cause air velocity of 25 fpm or greater at the face of the fume hood. Diffusers shall:

  – Be located at least 5 feet from the face of any fume hood

  - Be located to the side of the hood rather than in front of the hood
  - Shall not “short circuit” the airflow to a fume hood
  - Shall not blow directly on fire, vapor, or radioactivity detectors.

- All fume hoods must be capable of passing the criteria established in Section IV of Appendix XX of the Safety Manual, under “as manufactured” and “as installed” test conditions.

- The sash shall be equipped with a control device to maintain it at the operating height (e.g., releasable sash stops).

- All fume hoods shall be equipped with a low-exhaust flow alarm system designed to signal unsafe operating conditions whenever the average face velocity decreases below 90 percent of the specified AFV (e.g., 54 fpm when AFV is 60 fpm, and 90 fpm when AFV is 100 fpm). The alarm system shall consist of an audible and visual alarm to indicate malfunction or unsafe operating conditions. Additional utility and service requirements shall be indicated for each specific laboratory facility project.

- The noise exposure at the working position in front of the fume hood shall not exceed 70 dBa with the system operating and the sash open, nor shall it exceed 55 dBA at bench-top level elsewhere in the laboratory room. Each new fume hood installation shall be certified as meeting this requirement before initial use, and shall be recertified annually thereafter. Fans used in the exhaust systems servicing fume hoods shall be low-noise generating and corrosion-resistant to the fumes generated inside the fume hood. Total room performance with respect to noise levels must not exceed the Permissible Exposure Limits (PELs) specified in 29 CFR 1910.95.

6.3.10.2 Constant-Volume Fume Hoods

For this type of fume hood, 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 constant volume bypass-type fume hoods, and the face edges must be shaped to minimize entering air turbulence. Vertical foils on the sides shall be provided, because these are designed to deliver a slight airflow improvement by minimizing the eddies typically formed as air enters the hood. The work surface should be recessed ⅜ inch or greater, to facilitate effective containment of spills. 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 must always remain less than three times the design velocity (for a fully-open sash position).

- The bypass must provide a barrier between the fume hood space and the room when the sash is lowered.

- The bypass opening is dependent only on the operation of the sash. Select sash configurations are listed and described below:

  - The vertical-rising 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 thick, laminated safety glass. The sash system shall utilize a single-weight pulley and cable counterbalance system that is responsive to one-finger operation along the length of the sash pull. The counterbalance system must hold the sash in any position without creep and 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.

Installation of auxiliary air-type fume hoods (also called makeup air fume hoods) is prohibited at EPA facilities.

During non-operational times (nighttime, weekend, holidays), the decrease in exhaust volumes and air changes per hour (ACHs) must be balanced by an appropriate reduction in supply air/AHU fan speeds, in order to maintain negative pressure inside the laboratories and laboratory support rooms, with respect to corridors and other non-laboratory spaces.

6.3.10.3 VAV Fume Hoods

VAV fume hoods are conventional fume hoods equipped with a VAV control system that varies the exhaust volume (i.e., airflow) in proportion to the opening of the hood face (i.e., sash position). (*Note: VAV fume hoods are not the same as VAV air handling and supply systems; instead they involve varying the airflow through the fume hood only*.) The fume hoods and associated controls shall be installed per the manufacturer's specifications and must meet EPA's performance requirements (refer to Appendix XX of the Safety Manual). When multi-speed exhaust fans with VFDs are used, the device that controls both the supply and exhaust air volumes shall be actuated by a fume hood sash position sensor.

Response times for re-establishing the proper face velocity after a maximum change in sash position shall not exceed 5 seconds. The minimum airflow through a VAV fume hood must:

- Meet or exceed 25 cfm/ft^2 of fume hood work surface, with the sash closed for an unoccupied laboratory; or

- Limit the accumulation of potentially flammable vapors within the fume hood to less than 25 percent of their lower explosive limit (LEL).

As an alternative to relying on minimum airflows for preventing accumulation of vapors, fume hood interiors may be classified as described in NFPA 70, Article 500, and appropriate electric devices and equipment within the fume hood enclosure may be used. However, the minimum airflows still must be capable of maintaining the laboratories at a negative air pressure relative to adjacent corridors and non-laboratory administrative or support zones. Refer to NFPA 45 for guidance on electrical classification of fume hood enclosures.

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.

Per the Draft Revised ANSI/AIHA Z9.5-200X, *Laboratory Ventilation—Draft Standard*, VAV fume hoods and exhaust systems shall be equipped with emergency overrides that permit the maximum design flow even when the sash is closed. In situations where the main exhaust duct or manifolded duct is not required to be equipped with emissions controls, the project mechanical engineer shall consider use of an emergency exhaust duct that vents through appropriate treatment equipment (refer to “Fume Hood Emissions Controls” below. If used, the emergency exhaust duct shall be sized to accommodate 100 percent of the expected volumetric flow rate under design conditions.

6.3.10.4 Low Flow or High Performance Fume Hoods

Low flow or high performance fume hoods use various proprietary configurations to re-circulate a portion of the supply air within the hood or otherwise reduce the required exhaust airflow rate while maintaining safe conditions for the user. Specifications for different types of low flow or high performance fume hoods are as follows:

- *Tripled-Vaned Airfoil Type* (Fisher Hamilton or equivalent*)*: The bottom horizontal foil shall be a triple-vaned design to minimize reverse airflows and eddy currents at the work surface. The airfoil and sill shall be no greater than 0.5 inches above the height of the work surface. The airfoil shall provide a nominal 2-inch bypass when the sash is in the closed position, with area between vanes sufficient in size to pass through electrical plugs. The blower shall be an integral part of the chamber with dual-forward curved wheels. The blower motor shall be shaded-pole, low horsepower rated for a 30,000-hour duty cycle. The blower shall activate automatically when the sash is raised above the 18-inch open position.

- *Multi-Vector Airfoil Bypass* (Flow Safe or equivalent): A multi-vector airfoil bypass and dynamic turning vane or multi-vector bottom airfoil shall be mounted behind the sash, at the front edge of the work surface. The airfoil shall be permanently attached using spring-loaded pins to the hood assembly, allowing the airfoil to swing up for emptying the spill trough and for electrical cord access. The hood depth dimensions and vortex chamber shall be sized to support a bi-stable vortex. The bi-stable vortex control system shall be factory-installed and wired on the fume hood. The vortex control system shall include: (1) a dedicated variable face velocity (VFV) vortex pressure transducer controller, (2) a VFV electronic actuator, (3) a dedicated VFV hood alarm module, and (4) a linear trunnion damper.

- *Multi-Vector Bottom Airfoil* (Lab Crafters or equivalent): A multi-vector, slotted bottom airfoil shall be mounted behind the sash and above the work surface. The airfoil shall be capable of swinging up to pass line cords underneath and to clear spillage from the trough. A vortex control system shall be factory-installed and wired on the fume hood, and shall include: (1) a controller/monitor with vortex sensor, and (2) a baffle actuator. The vortex sensor component shall be surface-mounted in the fume hood sidewall and shall detect the pressure difference between a stable and unstable vortex (the manufacturer will indicate the transition threshold for an unstable vortex). The baffle controlled shall be mounted on the fume hood post and shall control the electric servo-motor that actuates automatic back wall baffles to maintain a stable vortex in the fume hood. The electric servo-motor shall be 24 volt AC, 0-10 volt DC input; 90 degree angle of rotation, current limited.

- *Upper Air Dilution Supply, Baffles, and Airfoil* (Labconco or equivalent): The hood shall have an upper dilution air supply for bypass air to sweep the sash interior and upper interior and provide between five and 10 percent of the hood’s air volume requirements. The hood shall be equipped with a perforated primary baffle and secondary baffle to limit air roll patterns. A perforated airfoil shall be provided across the bottom of the sash area to allow airflow into the hood regardless of the user’s position. The hood shall also be equipped with a perforated sash handle to bleed air into the hood chamber and direct contaminants away from the user’s breathing zone.

- *Other Fume Hood Designs*: As specified by the manufacturer. The design must be capable of meeting EPA's Performance Requirements in Appendix C of the Safety Manual.

6.3.10.5 Fume Hoods with Horizontal Sashes and Other Non-Standard Features

Horizontal sashes, as well as other non-standard features (larger-than-usual openings in distillation fume hoods, vented sinks, fume hoods larger than 6 feet), may be used under the following conditions:

- A conventional fume hood does not meet the specific requirements of the user (this should be reflected in the standard operating procedures [SOPs])

- The fume hood is used as intended by the manufacturer (i.e., the fume hood is not altered after installation)

- The fume hoods and associated controls meet EPA's performance requirements (refer to Appendix XX of the Safety Manual).

Note that horizontal sashes may put additional demands on VAV performance.

6.3.10.6 Fume Hood Lighting and Utilities

Specifications for lighting and electrical service inside fume hoods are contained in Appendix XX of the Safety Manual.

Specifications for laboratory service plumbing fittings, including those to be used inside fume hoods, are contained in Section 6.10.2.5. Plumbing services shall consist of remote control valves, as selected located within the end panels, controlled by extension rods projecting through the control panels of the hood, with color-coded plastic handles. All plumbing fittings shall be factory-installed and piped between the valve and the outlet.

Fully-enclosed service channels shall be provided on each fume hood sidewall, creating cord and service line access from the hood interior to the exterior front face.

6.3.10.7 Radioisotope Hoods

Radioisotope fume hoods shall meet all requirements listed above for constant volume bypass-type or VAV fume hoods, except that the interior liner material shall have:

- Panels at the sides, back, top, and plenum enclosure constructed of 18-gauge Type 302 stainless steel; and

- Structural members, reinforcements, and brackets constructed of 16-gauge Type 302 stainless steel.

The work surface should be 14-gauge Type 302 or Type 304 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 at least one ton of lead brick shielding. In addition, the work surface shall be reinforced from the underside with heavy steel grating to provide the necessary strength for holding lead brick for radiation protection and/or shall be capable of supporting at least 200 pounds per square foot (psf). The flooring system beneath the cabinet must also be designed to support at least 200 psf, sum of dead and live loads (refer to Chapter 5 for additional structure requirements). Emissions controls for radioisotope fume hoods are discussed in Section 6.3.10.11 below.

6.3.10.8 Perchloric Acid Hoods

In addition to the features described for constant volume bypass or VAV fume hoods, perchloric acid fume hoods must meet the following specifications:

- They shall be constructed from materials that are non-reactive, acid-resistant, and relatively impervious. Type 316 stainless steel with welded joints should be specified. Corners shall be rounded to facilitate cleaning. Work surfaces shall be watertight, with an integral trough at the rear of the hooded area, for collection of wash-down water.

- 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 fume hood, with an easily accessible strainer to filter out particulates. The wash-down system shall be activated immediately after the fume hood has been used.

- All welded ductwork shall be installed with a minimal amount of horizontal runs and no sharp turns. Perchloric acid fume hoods may not share ductwork with any other fume hood(s).

- 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.

Unless otherwise directed by the EPA project manager, exhaust from perchloric acid fume hoods shall be directed through scrubbers meeting the specifications detailed below under “Fume Hood Emissions Controls.”

6.3.10.9 Special Purpose Hoods

Special purpose fume hoods are defined as any fume hood that does not conform to the specific types described above in this subsection. Special purpose fume 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 [AA], or gas chromatography/mass spectroscopy [GC/MS] units). Other applications might present opportunities for achieving contamination control with less bench space or less exhaust volume (e.g., using the fume hoods as special mixing stations, sinks, evaporation racks, heat sources, or ventilated worktables). Special-purpose exhaust fume hoods shall be designed in accordance with ANSI/AIHA Z9.2,NFPA 45, and the ACGIH’s *Ventilation Manual* (most recent edition). Appropriate applications for specific types of special purpose fume hoods are described below:

- <u>Canopy Exhaust (Capture) Hoods</u>: These shall be provided as required for the removal of heat from specific laboratory apparatus, such as furnaces, ovens, and sterilizers. Canopy hoods that have periodic use shall be equipped with a shut-off switch. Refer to the ACGIH’s *Industrial Ventilation—A Manual of Recommended Practice* publication (most recent edition) for requirements and specifications for canopy fume hoods. Generally, the use of canopy fume hoods shall be minimized, and any proposed for installation on a project must therefore be approved by the EPA project manager.

- <u>Flexible Spot Exhausts (Snorkels)</u>: These shall be required to remove chemical fumes or heat from specific laboratory instrumentation, such as high-performance liquid chromatography (HPLC), GC/MS, and AA units. In other cases, where approved by the EPA project manager, snorkel attachments may be used to provide supplemental ventilation such that the primary ventilation system is not over-sized. These snorkel ports shall each have individual start-up/shut-down controls. The project HVAC engineer, in consultation with the EPA project manager, shall determine the minimum exhaust rate appropriate for the intended use of the snorkel(s).

- Gas Cabinets: Special exhaust cabinets will be required to house individual toxic/pyrophoric gas cylinders (or pairs of cylinders). Leak detectors and low-exhaust flow alarms, as well as a gas purge system, shall be required to provide for safe exchange of cylinders. Exhaust flows shall be determined by the project HVAC engineer and EPA project manager, based on the expected type and rate of fume generation from the cabinet.

6.3.10.10 Fume Hood Exhaust Systems

Fume hood exhaust systems should be designed in accordance with the recommendations in the most recent editions of ACGIH's *Industrial Ventilation*, ANSI/AIHA Z9.5, and NFPA 45. Individual exhaust systems should be provided for fume hood(s) when: (1) the mixing of emissions from the individual hoods is inadvisable; or (2) the emissions must be filtered, scrubbed, or otherwise treated before discharge. Pressure in laboratories shall be maintained as negative with respect to adjacent areas.

Fume hood and equipment exhaust manifolds shall be constructed from polyvinyl chloride (PVC)-coated galvanized sheet metal or Type 316 welded stainless steel, depending on the specific laboratory function physical and chemical characteristics of the exhaust. Polypropylene and glass duct material shall be considered for highly corrosive exhaust applications. Exhaust ductwork from fume hoods shall not be of spiral construction and shall be sloped toward the hood for drainage of condensate. Fume hood exhaust ducts shall also be constructed with welded, longitudinal seams and welded transverse joints, or equivalent construction, in accordance with the requirements of Section 8, *Ductwork*, of ANSI/AIHA Z9.2. Fume hood ductwork also shall be installed in accordance with the requirements of NFPA 45, specifically:

- Both new and remodeled fume hoods shall be equipped with flow-measuring devices.

- Air exhausted from fume hoods shall not be re-circulated into the workspace.

- Air from laboratory units and laboratory work areas in which chemicals are present shall be continuously discharged, and the exhaust systems shall be maintained at a negative pressure (i.e., lower pressure than the pressure in normally occupied areas of the building).

Exhaust fans shall be installed at the end of each duct system, such that all ducts within the occupied areas of the building are maintained under negative pressure. Remote, belt- or direct-driven, centrifugal exhaust fans (or other type acceptable to the EPA project manager), meeting applicable Air Movement and Control Association (AMCA) standards, shall be provided for the fume exhaust system. Exhaust fan components (impellers, housing, etc.) shall be chemically compatible with the exhaust stream and corrosion-resistant. Roof-mounted exhaust fans shall have weather-proof housings. Any exhaust fans that may handle airstreams containing flammable or explosive gas concentrations shall be explosion-proof (i.e., non-sparking). Appropriate noise control and vibration isolation features shall be integral with the fan.

Wherever feasible and cost-effective, exhaust fans associated with fume hoods shall be equipped with variable speed drives (VSDs). Exhaust fans shall also be equipped with static pressure reset controls for off-hours operation.

Consistent with ANSI/AIHA Z9.5, exhaust from laboratory ductwork systems must be discharged in a location(s) and manner to avoid re-entry into the laboratory building (or entry into adjacent buildings) at concentrations above 20 percent of the allowable concentrations inside the laboratory (or adjacent buildings). These requirements must be achieved under any wind or atmospheric conditions. Fume hood exhaust stacks shall be constructed without caps, rain hats, or other covering, as these can reduce exhaust plume buoyancy.

To optimize the effective stack height and exit gas velocity at the required exhaust flow rate(s), the EPA project manager may require that a dispersion analysis be performed, using an acceptable computer model(s). Refer to the Labs21 publication, *Best Practice Guide: Modeling Exhaust Dispersion for Specifying Acceptable Exhaust/Intake Designs*, May 2005 (or most recent version). Also note that while commonly-used EPA screening models (e.g., SCREEN3, ISC) are relatively simple to apply and produce results rapidly, there are documented limitations to their ability to simulate downwash and wake effects due to structures within close proximity to the exhaust stack(s). For this reason, application of CFD models (and in certain complex cases, scale-model wind turbine simulations) may be required to ensure that downstream contaminant concentration limits established by ANSI/AIHA Z9.5 will be achieved.[15] (CFD modeling requirements are covered in Section 6.2.2) If a dispersion analysis is not required, the exhaust stack should extend a minimum of 10 feet above the adjacent roof level and operate at a minimum of 3,000 fpm exhaust discharge velocity.

For fume hoods in areas designated as Group H-5 in accordance with the International Building Code (IBC), emergency power systems must be installed. In addition, the exhaust ventilation system shall be designed to operate at a minimum of 50 percent of the normal fan speed while on emergency power, or at a higher rate if necessary to comply with safety, health, and environmental requirements.

6.3.10.11 Manifolding of Fume Hood Exhausts

Fume hood exhausts may be manifolded only where specifically allowed by NFPA 45, and the manifolds must comply with all applicable provisions of NFPA 45. Manifolded exhaust systems (where used) should incorporate staged, multiple fans with VSDs and control dampers to maintain a constant static pressure in the manifold. This type of configuration ensures a quick response to changing conditions within the fume hoods.

For additional guidelines on manifolding fume hoods, refer to the Labs21 publication, *Best Practice Guide: Manifolding Laboratory Exhaust Systems*, April 2007 (or most recent version).

6.3.10.12 Fume Hood Emissions Controls

In most situations, the exhaust from chemicals will be diluted enough and/or the quantities small enough to be exempt from Clean Air Act (CAA) regulations. However, local, state, and EPA requirements should always be reviewed for any new construction project that will add fume hoods. The aggregate amount of emissions from the facility and/or the quantities and rates of emission from fume hoods in certain cases may trigger (or contribute to existing) permitting requirements under Title V of the CAA or rules governing minor (non-Title V) sources. Additional information regarding potential CAA requirements for fume hoods and associated exhaust systems is provided in Volume 4 of this Manual.

If emissions controls are required, appropriate control devices (e.g., particulate filters, high-efficiency particulate air (HEPA) filters, scrubbers, activated carbon canisters) shall be installed. Equipment that condenses, traps, neutralizes, or polymerizes[16] the hazardous substance(s)

[15] Petersen, R.L., B.C. Cochran, and J.W. LeCompte, *Specifying Exhaust Systems that Avoid Fume Reentry and Adverse Health Effects*, ASHRAE Transactions, Vol. 108, Pt. 2, 2002.

[16] Using an initiator compound to convert a substance to a solid or gel with low vapor pressure (e.g., acrylonitrile).

before it exits the fume hood should always be considered where feasible, because the quantity of waste requiring disposal will typically be 100 to 1,000 times less than that associated with capturing the contaminant from the airborne exhaust with a scrubber or activated carbon bed.[17] Where utilized, scrubbers shall be configured with countercurrent flow between the airstream and the reagent, to maximize removal efficiency. Scrubbing liquid shall be captured in a sump below the scrubber, and a recirculation system (pump and piping) shall be provided to aid in conserving the reagent chemical. The following sensors and controls shall be provided:

- A liquid level sensor and controls on the sump, to initiate makeup water flow at low level and shut down air flow at high level
- A pH probe and controller, to trigger additional reagent chemical flow when required
- A conductivity meter and controls that measures total dissolved solids (TDS) and activates a blow-down valve to drain excess salts.

An in-line filter also shall be provided in the recirculation loop to remove particulates that are likely to be captured by any scrubber (in addition to the targeted chemical[s] of concern).

Scrubbers for control of corrosive fumes shall be located as close as possible to the fume hood(s) or else be constructed of a suitable corrosion-resistant material.

Activated carbon beds shall be equipped with sampling ports, to aid in assessing when contaminant breakthrough has occurred (or better, is about to occur). The operation and maintenance (O&M) manual for the carbon beds should also specify the expected life to break-though at various concentrations and exhaust air flow rates for the contaminants of concern. Used carbon shall be disposed, where necessary as hazardous waste, in accordance with Volume 4 of this Manual.

Unless otherwise directed by the EPA project manager, HEPA filters will be required to manage exhaust from fume hoods in which radiological, bio-hazardous, or chemical agents are handled. HEPA filters shall have an efficiency of 99.97 percent for particulates of 0.3 microns or greater, as determined by the dioctyl phthalate aerosol test, and shall satisfy ASHRAE 52.2. HEPA filter housings shall be designed to minimize any possible contact or exposure to the contaminants of concern during filter change-outs. Guidance on the selection and design of radioactive air-cleaning devices can be found in the Energy Research and Development Administration's Publication 76-21, *Nuclear Air Cleaning Handbook* and in ANSI/ASME N509. Additional requirements for HEPA filters are contained below in Section 6.4.2.

6.3.10.13 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 activities. These types of enclosures have special design requirements for their intended uses. Ventilated devices (other than fume hoods) used to control hazardous materials must be approved on a case-by-case basis by EPA SHEMD and AEAMB. Ventilated devices used for removal of heat or nuisance odors must comply with the parameters set forth in ACGIH's *Industrial Ventilation*. Additional, specific requirements are as follows:

- <u>Glove Boxes</u>: 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.

[17] Hitchings, D.T., *Fume Hood Scrubbers*, SAFELAB Corporation, September/October 1993.

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 and the American Glove Box Society's Standard AGS-G001, *Guideline for Glove Boxes*, February 2007 (or most recent edition).

- 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 certification, performed by an NSF 49-listed, competent technician and conducted according to the procedures outlined in NSF 49, will be required once the cabinet(s) is/are installed. The classification of each cabinet shall be determined in consultation with the laboratory manager and staff. These types of cabinets have special design requirements depending on their intended use, as follows:

    - Protecting personnel from harmful agents inside the cabinet

    - Protecting the work product, experiment, or procedure from contamination by the laboratory environment and thus precluding invalid test results; and

    - Protecting the laboratory environment from contaminants inside the cabinet.

- Flammable Liquid Storage Cabinets: Cabinets for the storage of OSHA Class I, Class II, and Class IIIA flammable liquids shall be provided in accordance with the design, construction, and storage capacity requirements stated in NFPA 45. The project fire protection engineer shall ensure that, consistent with local codes, all regulated cabinets are mechanically vented to the outside, as follows:

    - 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 length of rigid steel tubing that has an inside diameter no smaller than the vent opening.

    - 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 feet.

    - The design velocity of the duct should not be less than 2,000 fpm per Table 3-2 of ACGIH *Industrial Ventilation,* (most recent edition)

    - The cabinets shall be marked in conspicuous lettering, *"Flammable—Keep Fire Away."*

  Cabinets not required to have venting nonetheless shall be sealed with the bungs supplied with the cabinet or with bungs specified by the manufacturer of the cabinet.

6.3.10.14 Bio-safety in Microbiological and Biomedical Laboratories

EPA has facilities with up to Bio-safety Level 3 (BSL-3) capabilities (defined below). Any such facilities shall be constructed and operated in accordance with U.S. Department of Health and

Human Services (HHS), Centers for Disease Control and Prevention (CDC), *Bio-safety in Microbiological and Biomedical Laboratories*. The following requirements for secondary barriers are mandatory for BSL-3 facilities:

- Ventilation System: A ducted exhaust air ventilation system shall be provided. This system shall create directional airflow that draws air into the laboratory from “clean” areas and toward “contaminated” areas. The exhaust air may not be re-circulated to any other area of the building. Filtration and other treatment processes for the exhaust air should be considered based on facility requirements and operations, including types of agents handled. The outside exhaust must be dispersed away from occupied areas and air intakes and directed through a HEPA filter.

- Airflow Monitoring Sensor(s): It is recommended that a visual monitoring device that indicates and confirms directional inward airflow be provided at the laboratory entry. Consideration should be given to installing an HVAC control system to prevent positive pressurization of the laboratory. Audible alarms that notify personnel of HVAC system failure should also be considered.

- Exhaust Air Management: HEPA-filtered exhaust air from a Class II BSC can be re-circulated into the laboratory if the cabinet is tested and certified at least annually. When exhaust air from Class II BSCs is to be discharged to the outside through the building exhaust system, the cabinets must be connected in a manner that avoids any interference with the air balance of the cabinets or the building exhaust system (e.g., an air gap between the cabinet exhaust and the exhaust duct). When Class III BSCs are used, they should be directly connected to the exhaust system. If the Class III BSCs are connected to the supply system, it shall be accomplished in a manner that prevents positive pressurization of the cabinets.

  Continuous flow centrifuges or other equipment that may produce aerosols must be contained in devices that exhaust air through HEPA filters before discharge back into the laboratory. The HEPA filters must be tested at least annually and meet the performance criteria specified in Section 6.3.10, “Fume Hood Emissions Controls” above. Alternatively, the exhaust from such equipment may be vented to the outside if it is dispersed away from occupied areas and fresh air intakes. Vacuum lines shall be protected with liquid disinfectant traps and HEPA filters or an equivalent mode of emissions control.

- Miscellaneous SHEM Measures. Additional environmental protection (e.g., personnel showers, HEPA filtration of exhaust air, containment of other piped services, and effluent decontamination) should be considered if recommended by the Agent Summary Statement, as determined by risk assessment; site conditions; or other applicable Federal, state, or local regulations.

6.3.11 Kitchen/Food Service Areas

Kitchen areas shall be maintained at negative pressure relative to adjacent dining rooms, serving areas, and corridors. Tempered make-up air shall be introduced at the kitchen hood and/or the area adjacent to the kitchen hood for at least 80 percent of exhaust air. Duct air velocity in the grease hood exhaust shall be no less than 1,500 fpm to 1,800 fpm (or as required to hold particulate in suspension). Dishwashing areas must be under negative pressure relative to the kitchen, and dishwashers shall be provided with their own exhaust hoods and duct systems, constructed of corrosion-resistant material.

6.3.12 Under-floor Air Distribution Systems (UFAD)

All UFAD AHUs and systems shall be designed in accordance with the U.S. General Services Administration's (GSA's) Publication, *GSA PBS Guidelines for Raised Floor Systems, With and Without Under-floor Air Distribution* (RF/UFAD Guidelines). All building areas to be considered for UFADs should be carefully evaluated on a case-by-case basis. In general, the areas that are most suitable for UFADs include:

- Computer rooms and other information technology or electronic equipment spaces
- General open office areas
- Training and conference areas
- Data centers.

UFAD systems shall not be installed in any laboratory spaces except in parts of a laboratory used strictly for office activities or non-chemical dry goods storage.

Where UFAD systems are installed, special care is required to ensure that the floor surface temperatures, as well as air temperatures and velocities near the floor, will not result in thermal discomfort within the work area. At a minimum, the conditions listed in Section 6.2.3 of this Manual must be maintained at all elevations between 6 inches and six feet above the finished floor in all occupied zones. However, the temperature values shown in Table 6-1 are for dry bulb temperatures where the air speed is less than 40 fpm and net thermal radiant exchange between the occupants and surrounding surfaces is negligible. Therefore, for UFAD systems, where occupied areas are in close proximity to the floor grilles or diffusers that have air velocities exceeding 40 fpm, the acceptable values in Table 6-1 shall be in terms of "operative temperatures," as defined in ASHRAE 55.[18]

Supplementary perimeter heating may be required to ensure that required temperatures are maintained in the perimeter areas of each floor. The project mechanical engineer shall include perimeter heating systems in the design, where necessary.

To achieve these conditions, UFAD systems require control of five additional factors not associated with ceiling air distribution systems:

- Heat transfer through the structural slabs that form the platforms for the raised floor (i.e., the bottom surfaces of the UFAD plenums)
- Incremental heat, infiltration, and water vapor transmission through exterior wall surfaces that interface with the UFAD plenums, which are approximately 10°F lower than typical occupied zones
- Heat transfer through the floor panels to the plenum
- Precise air temperature and static pressure distributions throughout the UFAD plenums

[18] Operative temperature is one of several parameters devised to measure air's cooling effect on the human body. It is a function of the mean radiant temperature, mean air temperature, mean skin temperature, and air speed.

- Plenum cleanliness and leakage control.

Supplemental perimeter heating and/or cooling systems are typically required when UFAD is employed. When these heating or cooling systems are activated (either automatically by a BAS or by manual thermostats), conditioned air may migrate into the core space being served by the UFAD system and affect occupant comfort in that space. Therefore, on floors with UFAD systems, perimeter zone pressure and/or temperature sensors shall be installed, which (through the BAS) equilibrate core space temperature and pressure, as necessary, after the perimeter systems are activated.

Refer to Section 12 of the GSA RF/UFAD Guidelines for additional technical direction and specifications. Additional technical design and performance information has been developed by Baumann, Webster, and others and can be accessed at www.cbe.berkeley.edu/underfloorair/.

6.3.13 Photocopy Rooms and Similar Areas

Where hazardous gases or chemicals may be present or used (including garages, housekeeping/laundry areas, and copying/printing rooms), each space shall be sufficiently exhausted to create a negative pressure with respect to adjacent spaces, when the doors to the room are closed. For each of these spaces, self-closing doors shall be provided, and the space shall have either deck-to-deck partitions or a hard lid ceiling. The exhaust rate shall be at least 0.5 cfm/ft^2, with no air recirculation. The pressure differential between the space and surrounding spaces shall be at least 5 Pa (0.02 inches of water gauge) on average and 1 Pa (0.004 inches of water gauge) at a minimum when the doors to the room are closed.

High-volume copy, print, and fax equipment shall be located away from occupant work spaces, in enclosed rooms with self-closing doors. In order to effectively remove airborne contaminants generated by this type of equipment, the rooms must be physically separated from adjacent spaces. As noted above, this may be accomplished through installation of deck-to-deck partitions or sealed gypsum board enclosures. To remove airborne contaminants and prevent cross-contamination into occupied spaces, copy, print, and/or fax rooms must be equipped with a dedicated exhaust system (no return air) that creates a negative pressure within the room as discussed above. Convenience (small) copier and printer use should be minimized where possible.

Chemical storage and mixing areas, such as janitor's closets and photo labs should also be located away from occupant work areas. Additionally, these rooms must be physically separated from adjacent spaces via installations of deck-to-deck partitions or sealed gypsum board enclosures. These rooms also must be equipped with a dedicated exhaust system (no return air) that creates the required negative pressurization to ensure that cross-contamination into adjacent occupied spaces will not occur.

All building HVAC systems must be designed to accommodate filtration systems with a MERV of 13 or better. The requirements for a MERV 13-rated filter are contained in Table 6-1:

EPA facilities can earn one point toward LEED-NC 2009 certification by ventilating all occupied spaces by at least 30 percent above the minimum rates required by ASHRAE Standard 62.1 (latest version). The ventilation rates are calculated in the breathing zone, and conformance with this credit will be measured based on the performance of the building ventilation systems. In many situations, UFAD systems can aid in improving ventilation and in attaining this LEED credit.

Table 6-1: Requirements for a MERV Value 13 Filter

Composite Average Particle Size Efficiency (%)	Minimum Final Resistance

0.30 – 1.0 µm	1.0 – 3.0 µm	3.0 – 10.0 µm	(Pa)	(in W.G.)
< 75%	≥ 90%	≥ 90%	350	1.4

µm – micrometers; Pa – Pascals; in W.G. – inches of water gauge

The air handling units must be designed to accommodate the required filter sizes and pressure drops. These exhaust systems must be included in the same commissioning and measurement and verification (M&V) programs as other ventilation systems within the facility.

6.4 Indoor Air Quality (IAQ) Requirements

6.4.1 Ventilation Rates

The outdoor air ventilation rates specified in ASHRAE 62.1 are the minimum acceptable ventilation rates for EPA buildings. Instrumentation and controls shall be provided to assure outdoor air intake rates are maintained during occupied hours. Where occupancy requirements are likely to generate high levels of airborne particles, special air filtration shall be provided on the return air system, or dedicated and localized exhaust systems shall be utilized to contain airborne particulates.

The following spaces shall be maintained under a negative pressure relative to surrounding spaces—using the control method specified below—and fully exhausted outside the building, with a minimum of 10 ACHs:

- Copy rooms – using occupancy sensors for control
- Toilet rooms – integrated with building ventilation control
- Break rooms/pantries or kitchens – using occupancy sensors for control
- Battery/rectifier/uninterruptible power supply (UPS) rooms – using thermostats with occupancy sensor override controls
- Generator rooms – using thermostats with occupancy sensor override controls
- Janitorial closets – integrated with building ventilation control with separate exhaust.

6.4.2 Air Filtration Systems

Air filtration shall be provided in every air handling system. AHUs shall have a disposable pre-filter and a final filter. The filter media shall be rated in accordance with ASHRAE 52.2. The pre-filters shall have a minimum efficiency reporting value (MERV) of 8 (30 to 35 percent efficient with a maximum allowable particle size of 10 microns [µm]), while the final filters shall have a MERV of 13 (80 to 90 percent efficient with a maximum particle size of 1 µm). Filter racks shall be designed to minimize the bypass of air around the filter media; the maximum allowable bypass leakage shall be 0.5 percent. All filtration system designs must be approved by AEAMB and SHEMD prior to construction.

Air filters for ductwork and equipment installation shall be easily removable, serviceable, and maintainable. The in-service face velocity of each air filter shall be capable of achieving the specified efficiency at the lowest possible pressure drop. Filters shall be constructed of non-combustible materials that meet the requirements of UL 900, for Class I units. Air filters shall be located on the suction side of fans and coils and in other locations, as required for effective removal of particulates. 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. Differential pressure transducers that supply real-time pressure measurement data to the building automation system (BAS) shall also be installed, where practicable.

ASHRAE 52.1 guidelines shall be used for specifying the efficiencies required for medium-efficiency filters. Filters shall be specified, and installed for use with one of the following classifications: pre-filter, medium-efficiency filter, or high-efficiency filter.

6.4.2.1 High-Efficiency Particulate Air (HEPA) Filtration

HEPA filters are defined as filters that remove at least 99.97 percent of airborne particles greater than 0.3 µm in diameter. It is good practice to install a pre-filter ahead of a HEPA filter to prolong the life of the HEPA filter. In general, bag-in/bag-out filter housings should be used to minimize the spread of contaminants when the HEPA or pre-filter is changed.

EPA facilities can earn one point toward LEED-NC 2009 certification if, prior to occupancy, they install new air filters meeting a minimum efficiency reporting value (MERV) of 13 or higher. (There are additional requirements for this credit, which are documented in the LEED Reference Guide).

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 when designing the system. The pressure drop across HEPA and pre-filters should be monitored and linked to an alarm, indicating the need for filter change-out. The filter plenum should be located on the inlet side of the filtration assembly, to allow the fan to be serviced from the clean side of the filter. It is good practice to allow a straight run of approximately four 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.

The chosen location(s) for HEPA filters shall facilitate in-place testing of the filter banks, 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 (e.g., electrical receptacles and “plant” compressed air) shall be extended to the plenum location to facilitate in-place testing. In-place testing design requirements shall meet all the recommendations of UL 586 and ASME N510.

HEPA filters shall be provided with fire protection. The fire protection design shall sufficiently separate pre-filters (or fire screens equipped with water sprays) 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 the 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 building’s master fire protection system in the room or building in which the filters are located. Refer to Chapter 9 of this Manual for additional information.

6.4.3 Air Cleaning Devices for Special Applications

Air cleaning devices for special applications may include dry-type dust collectors, wet collectors, centrifugal collectors, absorbers, oxidizers, electrostatic precipitators (ESP), and/or chemical treatment media, 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. These devices shall be designed according to the requirements given in the project criteria, the

ASHRAE *Handbook—HVACR Systems and Equipment* and ACGIH's *Industrial Ventilation: A Manual of Recommended Practice for Design.*

6.4.4 Operations and Maintenance (O&M) of Air Cleaning Systems

All air cleaning systems shall be designed for continuous operation, 24 hours a day, 7 days a week, unless otherwise specified in the project criteria.

The air supply and exhaust plenums shall be designed so that motors, bearings, control valves, and steam traps are easily accessible for maintenance. Refer to Section 6.2.5 for additional guidelines regarding maintenance access.

6.4.5 Location of Air Intake(s)

The outside air intake(s) shall be located to provide the cleanest possible source of fresh air for the building and shall be located outside the probable discharge areas for plumes of contaminated air from exhausts and vent stacks. Exhausts and vent stacks include, but are not limited to:

- Fume hood exhausts
- Vehicle exhausts
- Exhausts from adjacent structures
- Sources of potential microbial contamination, such as vegetation, organic matter, and bird and animal droppings.

For buildings of more than four stories, fresh air intakes shall be located on the fourth floor or higher. For buildings of three stories or less, intakes shall be located high on the building walls (preferred) or on the roof, if wall-mounting is impracticable.

Special care shall be exercised not to locate mechanical air intakes within or near the loading dock area. Air intakes also shall be located in accordance with HHS/NIOSH Publication 2002-139, *Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks*. However, protection from such attacks shall not be provided at the expense of introducing other potential contaminants (e.g., building exhausts) into the ventilation system. In addition, Table 6-5 provides a guide for minimum separation distances between ventilation air intakes and other building features, as listed in GSA Publication P-100, *Facilities Standards for the Public Buildings Service*:

Table 6-5: Air Intake Minimum Separation Distance

Object	Minimum Distance (feet)
Property line	3
Garage entry, loading dock	25
Driveway, street or public way	10
Limited access highway	25
Grade	50
Roof*	1
Cooling towers or evaporative condensers	15 – 25**

Table 6-5: Air Intake Minimum Separation Distance

Object	Minimum Distance (feet)
Exhaust fans and plumbing vents	10
Kitchen supply and exhaust air	25

* Roof intakes must be at least 8 inches above the average maximum snow depth, and the potential for drifts at the intake location must be considered. Outdoor intakes should be covered by 0.5-inch mesh screen. The screen should be of corrosion-resistant material and located outside of, or no more than, 8 inches inside of the outside face of the intake grille, louver, or rain hood entry. On buildings of more than four stories, the outside air supply louvers shall be located on the fourth level of the building or higher. On buildings of three stores or less, locate the intake on the roof or as high as possible. Locating intakes high on the exterior wall is preferred to a roof location. Outside air intakes are not permitted within 25 feet of a loading dock or any other fume-producing areas.

** Fifteen (15) feet is the minimum distance specified for cooling tower intakes in ASHRAE 62.1, and 25 feet is the minimum distance specified for cooling tower exhausts. In addition, as noted by Burton, D.J., *IAQ and HVAC Workbook*, (most recent edition), cooling towers within 15 feet of air intakes should be fitted with mist eliminators.

6.4.6 Air Flow Characteristics Study

The location and design of the exhaust stacks (and fresh air intakes) to avoid adverse air quality impacts shall be based on criteria developed by a study of prevailing wind patterns. The study shall utilize recognized wind modeling techniques, such as the EPA's Industrial Source Complex Model (ISC3), the Briggs Plume Rise Equations, and the design criteria of Chapter 16 of the ASHRAE *Handbook—Fundamentals*, and Chapter 44 of the ASHRAE *Handbook—HVAC Applications*, as applicable. In addition, the study should take into consideration the recommendations of Section 5.16, Exhaust Stack Outlets, including Figures 5-29 and 5-30, of ACGIH *Industrial Ventilation*, 22nd (or most recent edition), as applicable.

6.4.7 Use of Permanent HVAC System During Construction

The permanent HVAC system may be used to move both supply and return air during the construction process only if the following conditions are met:

- A complete air filtration system, having filters with particulate removal efficiencies of 60 percent or greater, is installed and properly maintained.
- No permanent diffusers are used.
- No plenum-type return air system(s) are employed.
- The HVAC duct system is adequately sealed to prevent the spread of airborne particulate and other contaminants.
- Following the building "flush out," all duct systems are vacuumed with portable HEPA vacuums and documented "clean," in accordance with National Air Duct Cleaners Association (NADCA) publications *General Specifications for the Cleaning of Commercial HVAC Systems* and *ACR Standard—Assessment, Cleaning, and Restoration of HVAC Systems,* 2006 (or most recent edition).

Any ductwork to be reused and/or to remain in place shall be cleaned, clearance tested, and demonstrated to be clean in accordance with the NADCA requirements/recommendations. The cleaning, clearance testing, and demonstration shall occur immediately prior to EPA occupancy. Additional information regarding maintaining acceptable IAQ during construction activities is contained in Section 11.2 of this Manual.

HVAC system TAB should be conducted after any HVAC system alterations, or as part of commissioning activities for new construction or major renovations.

6.5 Heating Systems

6.5.1 Steam and Hot Water Distribution

6.5.1.1 District Steam Heating

District steam heating, if available, may be considered if determined to have long-term reliability and can be economically justified through a life-cycle cost analysis. In the event district steam heating is utilized, appropriate space must be provided to allow EPA to install boilers and associated equipment at a later date (i.e., should it choose to partially or completely withdraw from the district steam supply). If steam is furnished to the building, such as under a district heating plan, it shall be converted to hot water with a heat exchanger in the mechanical room near the entrance into the building. Unless this equipment is obtained or leased from the district heating company, the heat exchanger and all necessary appurtenances to enable connection with the district supply line shall be included as part of the design. EPA's preferred methods of management for any condensate generated by steam from a district energy (DE) supplier and produced on EPA's property are, in the following order:

- The DE supplier takes back the condensate and uses or disposes of it at a site(s) other than the EPA facility's property
- The EPA facility uses the condensate for non-potable application(s) on the facility's property, in an appropriate manner based on its physical and chemical parameters. One example might be directing the condensate through a heat exchanger for pre-heating domestic hot water
- The facility cools the condensate with non-potable water and disposes of it in compliance with existing wastewater discharge permit(s)
- The facility cools the condensate with potable (i.e., city) water and disposes of it in compliance with existing wastewater discharge permit(s).

If district steam heating is used, steam heating shall not be permitted inside the building other than conversion of steam-to-hot water in the mechanical room. In addition, the use of steam for HVAC applications shall be limited to the conversion of steam heat to hot water heat (as noted above), and for use in providing humidification to areas or processes within the facility. However, steam delivered from a central plant, a district steam system, steam boilers, or any equipment where chemicals are delivered into the medium resulting in the final product of steam shall not be used for the purpose of providing humidification to the HVAC system or occupied spaces.

6.5.1.2 Hot Water Piping

Hot water piping shall be designed and installed in accordance with the general requirements outlined in Section 6.7.2. In addition, hot water piping shall be one of the following:

- Cast steel pipe with welded or cast iron fittings
- Hard copper tubing, with cast brass, wrought copper, or wrought brass fittings.

Piping shall be sized based on the ASHRAE *Handbook—Fundamentals.* Design pressure drops of greater than 4 feet per 100 linear feet of piping may only be used for pipes greater than 2 inches internal diameter. The recommended design water velocities are between 2 feet per second (fps) and 7 fps, with up to 15 fps allowed by boiler feed service. Water flow (especially flow through heat transfer equipment) shall be directed to permit natural air venting. Air vents shall be installed at high points within the hot water system.

The preferred methods of accommodating the inevitable thermal expansion of hot water piping are by means of pipe geometry (e.g., offsets, changes in direction, and pipe loops). Offsets that would cause torsion should be avoided by using screwed fittings to prevent potential leaking joints. Expansion joints shall be used only where space does not permit proper geometry or installation of pipe loops. For expansion criteria as a function of temperature for steel and copper pipe, refer to Table 12 of MIL-HDBK-1003/8A, *Exterior Distribution of Utility Steam, High Temperature Water, Chilled Water, Natural Gas, and Compressed Air.*

Piping in-between expansion joints shall have supports designed to carry the weight of the pipe and fluid together with axial friction loads and the thrust of the expansion joint. Risers and mains should be anchored to prevent excessive strain on branches. Shields shall be provided between the pipe insulation and supports, and vertical pipes and main risers shall have base elbows designed to support the weight of the pipe from the elbow up to the first anchor. Hangers shall be massive enough to dampen undesirable vibrations, and spring hangers shall be included where required to accommodate expansion in vertical piping.

A water treatment evaluation shall be performed during the design phase based on analysis of likely make-up water source(s) and vulnerability of the selected pipe material to corrosion and/or scaling. Local regulations (e.g., publicly-owned treatment works [POTW] pre-treatment permit discharge prohibitions) must also be considered when selecting make-up water treatment technologies.

Pipes shall be marked in accordance with ASME A13.1 and Chapter 5 of the GSA Publication P-100.

6.5.1.3 Pumps

Pumps for hot water conveyance shall be centrifugal-type and shall generally be selected to operate at 1,750 rpm. Both part-load and full-load conditions must fall on the pump curve. The number of primary hot water pumps shall correspond to the number of boilers, and a standby pump shall be designed for each hot water circuit. Variable volume pumping systems shall be considered for all secondary piping systems with pump horsepower greater than 11.2 kW (15 hp).

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 levels in the system. Pumps shall also be equipped with relief valves, which shall be preset to lift at a lower pressure than the boiler's safety valve setting plus the design static and friction heads.

Each group of boiler pumps shall be arranged with piping, valves, and controls to allow each boiler group to operate independently of the other boiler groups. 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 (i.e., standby pumps) and high-efficiency motors shall be considered for pumps for all hot water and chilled water distribution systems.

Pumps also shall be selected in accordance with the guidelines contained in FEMP's publication, *How to Select an Energy-Efficient Centrifugal Pumping System*.

6.5.1.4 Expansion Tanks and Air Separators

This section applies to hot water system piping for operating temperatures less than 250°F (i.e., "low" temperature hot water, which will be the situation at most EPA facilities). System pressure control is required to:

- Limit pressure in all parts of the system to the allowable working pressure
- Maintain minimum pressure in the system to prevent cavitation and/or boiling of hot water
- Minimize make-up water addition.

Closed air cushion and diaphragm (bladder)-type expansion tanks will be permitted. Expansion tanks shall be located on the suction side of the system pump(s), such that system pressure will always be greater than atmospheric pressure. No shut-off valves shall be installed in-between the heat source and the expansion tank. Expansion tanks and ancillary piping shall be sized based on the ASHRAE *Handbook—HVAC Systems and Applications* and configured in accordance with Figures 14 and 15 of MIL-HDBK-1003, *Heating, Ventilating, Air Conditioning, and Dehumidifying Systems* (UFC 3-410-02N).

6.5.1.5 Heat Recovery from Condensate

Heat recovery from boiler condensate shall be considered during boiler system design. A heat exchanger(s) may be utilized to remove heat from condensate not returned to the boiler. This recovered heat can be used to pre-heat domestic hot water, boiler make-up water, or low-temperature water returned to a boiler or heat exchanger. This alternative shall be considered where technically feasible and life cycle cost-effective.

As specified above, EPA generally requires steam energy (whether generated in on-site or off-site boilers) to be converted to a separate hot water loop to service the building. However, in certain situations, a building may utilize dedicated steam lines for special applications (e.g., for sterilization, food preparation). In those instances, there may be opportunities to recover some of the heat contained in condensate produced in the steam piping. Condensate is continuously formed in steam systems when steam cools in the distribution lines due to losses, or when it performs work. A condensate receiver can be installed to reduce steam to atmospheric pressure and allow re-introduction into the boiler or reuse of the condensate for other applications. Condensate also may be recovered from steam traps inserted at suitable locations along piping runs.

6.5.2 Boilers

The heating plant shall be designed to 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—Fundamentals*, plus process heating loads (if any) and an allowance for piping energy losses.

The use of electric resistance and/or electric boilers as the primary heating source for the building is prohibited. All boilers shall comply with the ASME *Boiler and Pressure Vessel Code* (BPVC) (most recent version). In determining whether to select a steam or a high-temperature hot water (HTHW) system (a system that generates hot water above 300°F), the following factors shall be considered:

- Whether the system will be operated intermittently or continuously

- Whether rapid response of the system to significant load variations is important
- Hot water and condensate pumping costs
- Length, size, and configuration of required piping
- Possibility of using HTHW to generate the steam at its point of use (e.g., in a facility where only a few processes require steam supply).

Additional specific requirements for steam and hydronic (i.e., hot water) boilers are detailed in the following sections.

6.5.2.1 Standards

Heating equipment shall comply with the following standards, except where noted otherwise:

- Oil-fired heaters – NFPA 31
- Gas-fired heaters – NFPA 54
- Liquefied petroleum gas-fired heaters – NFPA 58
- Liquefied natural gas-fired heaters – NFPA 59A
- All boilers – NFPA 85.

6.5.2.2 Steam Boilers

Steam boilers shall be designed to produce dry, saturated steam unless superheated steam is necessitated by one or more of the following:

- The economics of electricity generation
- Meeting specific process requirements
- Accommodating extensive distribution systems.

If required for process steam, the use of high-pressure "satellite" boilers located close to the process/point of use shall be considered, in lieu of facility-wide distribution of high-pressure steam. Where steam boilers are used, the associated condensate recovery system(s) shall be designed and controlled to maximize the recovery and reuse of steam condensate.

6.5.2.3 Hydronic Boilers

Design and layout of hydronic heating systems shall follow the principles outlined in the most recent edition of the ASHRAE *Handbook—HVAC Systems and Equipment*. HTHW boilers shall be of the controlled, forced-circulation type and specifically designed for HTHW service. Because of costs associated with high-pressure pipes, valves, and fittings, HTHW systems should not be designed for higher temperatures and pressures than are absolutely necessary for the facility's requirements. For most EPA applications, the temperature and pressure of hydronic systems will be limited to 300°F and 160 psi, respectively. All hydronic boilers shall be:

- Dual-fuel (i.e., capable of operating on either natural gas or No. 2 fuel oil)

- Low-pressure (i.e., the maximum working pressure and temperature stated above)
- Installed in a dedicated mechanical room with all provisions made for breaching, flue stack, and combustion air.

In a gas-pressurized HTHW system, an inert gas (e.g., 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 effectively prevents hot water from flashing into steam.

Boilers shall be piped to a common hot water header, thus providing redundancy and enabling efficient part-load operation of the boiler system (e.g., taking individual boilers off-line when load requirements decrease). All units shall have adequate valve assemblies to provide isolation of off-line units without interruption of the required service. All backup boiler systems shall be provided with expansion tanks, heat exchangers, feed water treatment units, and air separators (either redundant equipment, or, in smaller applications, plumbed directly into the main systems via isolation gate valves).

6.5.2.4 Boiler Efficiency Requirements

Table 6-6 contains the FEMP specifications for commercial and institutional boilers:

Table 6-6: FEMP Efficiency Recommendations for Commercial Boilers[1]

Product Type (Fuel/Heat Medium)	Rated Capacity Range (BTU/hr)	Recommended Thermal Efficiency (e_t)[2]	Best Available Thermal Efficiency (e_t)[3]
Natural Gas/Water	300,000 – 2,500,000	80%	86.7%
	2,500,001 – 10,000,000	80%	83.2%
Natural Gas/Steam	300,000 – 2,500,000	79%	81.9%
	2,500,001 – 10,000,000	80%	81.2%
No. 2 Fuel Oil/Water	300,000 – 2,500,000	83%	87.7%
	2,500,001 – 10,000,000	83%	85.5%
No. 2. Fuel Oil/Steam	300,000 – 2,500,000	83%	83.9%
	2,500,001 – 10,000,000	83%	84.2%

1. These recommendations cover low- and medium-pressure boilers used primarily in commercial space heating applications. They do not apply to high-pressure boilers used in industrial processes and cogeneration applications.
2. Thermal efficiency (e_t), also known as “boiler efficiency” or “overall efficiency,” is the boiler’s energy output divided by energy input, as defined by ANSI Z21.13-2004, *Gas-Fired, Low-Pressure Steam and Hot Water Boilers.* In contrast to combustion efficiency (e_c), e_t accounts for radiation and convection losses through the boiler’s shell.
3. These “best available” efficiencies do not consider condensing boilers, which are generally more efficient but are not readily ratable using ANSI Z21.13.

BTU/hr – British Thermal Units per hour; ANSI – American National Standards Institute

6.5.2.5 Climate-Based Boiler Requirements

For northern climates (e.g., Zones 5 through 7 defined in ASHRAE 90.1), a minimum of three equally-sized boilers shall be provided. Each boiler shall have equal capacities, and the combined capacity of the three boilers shall be, at a minimum, 120 percent of the total peak load (space heating and humidification requirements). For southern climates (e.g., Zones 1 through 4 defined in ASHRAE 90.1), a minimum of two equally-sized units at 60 percent of the peak capacity (each) shall be provided. All boiler units shall be packaged, with all components and controls factory pre-assembled.

6.5.2.6 Fuel Storage

Where liquid fuel is used, provide an Underwriters Laboratory (UL)-listed, double-wall containment type storage tank. For specific requirements, refer to:

- NFPA 30
- NFPA 46
- Chapter 2 in Volume 3, *Safety and Health Requirements* (the Safety Manual)
- Chapter 5 in Volume 4, *Environmental Management Guidelines* (the Environmental Management Manual).

For facilities that are required to develop a Spill Prevention, Control, and Countermeasures (SPCC) plan, the requirements of that Plan will govern.

6.5.2.7 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.

6.5.2.8 Heat Recovery from Boiler Flues/Condensing Boilers

Hot flue gases from boilers can provide a source of waste heat for a variety of uses. Indeed, state-of-the-art condensing boilers use this principle (i.e., by removing enough heat from the flue gas for water vapor in the gas stream to condense). These types of boilers shall be considered and installed wherever possible, taking into consideration existing equipment configuration and life cycle cost-effectiveness. Note that heat exchangers used in flues must be constructed to withstand the often corrosive nature of flue gases as they cool.

The most common use of flue gas heat recovery is for pre-heating boiler feed water, although other applications are possible. The determining factor will be the amount of specific heat that can be transferred from the flue gas stream, since the water to be heated does not come into contact with the flue gas (thus, water quality is not a concern).

6.5.2.9 Boiler Meters and Controls

Boilers shall be equipped with meters to measure total potable water (or other water supply of acceptable quality) used as boiler feed water. Controls and relief valves to limit pressure and temperature must be specified separately. Burner controls shall be actuated based on return water temperature measurements, and control sequences (e.g., modulating burner control and outdoor air reset) shall be optimized. Boilers shall have self-contained microprocessor controls capable of connecting to the BAS. Refer to Chapter 8 of this Manual for additional information.

6.5.2.10 Gas Trains

Boiler gas trains shall be installed in accordance with UL/Factory Mutual/ASME CSD-1.

6.5.2.11 Automatic Valve Actuators

Gas valve actuators shall not contain sodium/potassium elements since these may pose a danger to maintenance personnel.

6.5.2.12 Venting

Products of combustion from fuel-fired appliances and equipment shall be delivered outdoors from the building through the use of breaching, vent, stack, and/or chimney systems. Breaching connections from fuel-fired equipment to vents, stacks, or chimneys shall be horizontal wherever possible and shall comply with NFPA 54. Vents, stacks, and chimneys shall be vertical and shall comply with NFPA 54 and NFPA 211. Breaching, vent, stack, and chimney systems may operate under negative, neutral, or positive pressure (depending on the application) and shall be designed based on:

- Flue gas temperature and dew point
- Length and configuration of the system
- Vent pipe insulation characteristics.

Venting materials shall be factory-fabricated and assembled in the field. The vents may either be double-wall or single-wall construction, depending on the distance from adjacent combustible or non-combustible materials. Material types, ratings, and distances to adjacent building materials shall comply with NFPA 54 and NFPA 211.

6.5.2.13 Boiler Water Treatment

Boiler water treatment shall be provided to prevent deposits onto, or corrosion of, internal boiler surfaces, and to prevent the carryover of boiler water solids into the steam or hot water supply. Water quality measures for the heating plant and for other site process water users should be coordinated, and water conservation measures shall be implemented wherever feasible and life-cycle cost-effective. These measures may include use of reclaimed water (e.g., collected rain water) as feed water, recovery and use of condensate and blow-down water, or other measures.

The design of the boiler water treatment 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 treatment chemicals. Continuous versus intermittent blow-down operations shall be considered to determine which system will keep the concentration of total solids within acceptable limits. For continuous blow-down operations, the economics of installing a heat recovery system shall be considered. Blow-down rates and boiler water chemistry control shall be established in accordance with ASME's *Consensus Operating Practices for Control of Feed Water/Boiler Water Chemistry in Modern Industrial Boilers*.

In accordance with OSHA regulations (29 CFR 1910.151), an emergency eyewash (shower type) must be provided in any work area(s) where treatment chemicals are being handled.

6.5.2.14 Cogeneration

The use of a cogeneration plant as a possible alternative may be considered in the planning of any large steam generation facility. A rigorous economic analysis (i.e., life cycle costs and reasonably anticipated revenue from electricity or steam sales) shall be performed for any proposed cogeneration project to ensure that the project will be financially viable and advantageous to EPA. Appropriate error bands and assumptions shall be defined for energy costs and prices, and a sensitivity analysis shall be performed.

The feasibility of cogeneration with HTHW boilers or HTHW-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, and seasonal variations
- Utility rate structures
- Regulatory concerns:
  - Public Utility Regulatory Policies Act (PURPA)
  - Relevant Federal environmental regulations
  - Current state and local regulations.

The applicability of cogeneration shall be thoroughly evaluated in accordance with guidelines developed by EPA Cogeneration Partnership Program. Cogeneration plants, where used, shall be sized to accommodate existing loads.

6.5.2.15 Boiler Plant Insulation

All hot surfaces within 7 feet of the plant floor (or on any catwalk) shall be insulated to prevent surface temperatures above:

- 140°F, in areas where contact would be unintentional and unlikely
- 120°F, in areas where contact is likely or necessary for equipment operation.

Insulation shall conform with the manufacturer's recommendations and the ASHRAE *Handbook—Fundamentals*.

6.5.2.16 Modular Boilers

Multiple or modular boiler installations shall be considered for all applications, in order to maintain high operating plant efficiency and part-load utilization fraction throughout the year. The number and size of the boilers shall be based on the number of operating hours at full-load and part-load operation, the turn-down ratio of the boilers being considered, part-load efficiency, and year-round process loads. For laboratories, the Labs21 guidelines contained in the *Technical Bulletin: Modular Boiler Systems for Laboratory Facilities* shall be followed.

Use of a dedicated, base-load boiler shall be considered where a year-round process demand exists. The possibility of operating small local boilers rather than the central heating plant to satisfy individual process loads shall also be considered. 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 or hot water users is required
- Requirements exist for several different steam pressures
- Variable steam and/or hot water loadings exist with respect to time or quantity.

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.

6.5.2.17 Flue Gas Heat Exchangers

Use of flue gas heat exchangers in condensing or non-condensing boilers shall be considered as stated in Section 6.5.2. Efficiency increases approximately 1 percent for every 10°F increase in feed water temperature. Under all anticipated operating conditions, the stack temperature shall remain above the carbonic acid dew point, in order to prevent flue damage (*carbonic acid is formed from the dissolution of CO_2 in the stack gas*).

6.5.3 Forced Air Furnaces

Based on the ENERGY STAR® Program Requirements for Furnaces, *Partner Commitments Version 2.1 – Draft 1*, a forced air furnace is defined as a heating unit with a heat input rate of less than 225,000 BTU/hr whose function is the combustion of fossil fuel for space heating with forced hot air. The unit must include burner(s), heat exchanger(s), blower(s) and connections to heating ducts. Furnace efficiency is measured in Annual Fuel Utilization Efficiency (AFUE). AFUE measures the amount of fuel converted to space heat in proportion to the amount of fuel entering the furnace, and is commonly expressed as a percentage (test procedures developed by DOE are specified in 10 CFR Part 430, Appendix N).

Forced air furnaces must meet the following requirements for ENERGY STAR® Tier II criteria, which took effect on October 1, 2008:

- Natural gas: ≥ 92% AFUE rating
- Fuel oil: ≥ 85% AFUE rating.

In addition to the above criteria, the following requirements shall be met:

- A manufacturer warranty must be provided.
- The use of high-efficiency electric motors for blowers should be considered.

6.5.4 Heat Pumps

When considering the use of heat pumps, a thorough engineering analysis shall be performed. The requirement for possible supplementary heating (and the frequency and duration of such) must be evaluated, as this represents an “energy penalty” for the heat pump option. Heat pumps shall be selected on the basis of engineering feasibility and life cycle cost-effectiveness. The following configurations shall be considered:

- Ground source (geo-exchange) heat pumps, using wells or ponds as a heat source or perhaps imbedding a closed-loop heat rejection circuit in a parking lot as a “heat exchanger” (refer to Section 6.5.5 for a detailed discussion of geo-exchange heat pumps)
- The use of water-source heat pumps, utilizing a closed water loop system, where the perimeter spaces of a building must be heated and the interior must be cooled concurrently.

FEMP and ENERGY STAR® minimum performance requirements for air-source and water-source heat pumps are contained in Table 6-7:

Table 6-7: FEMP and ENERGY STAR Air-Source and Water-Source Heat Pump Efficiency Recommendations

Product Type and Size			Recommended Level[1]	Best Available[2]
FEMP Recommendations	Air-Source[3] < 65 MBtu/hr		≥ 12.0 SEER ≥ 7.7 HSPF	13.2 SEER 8.5 HSPF
	Air-Source 65 – 135 MBtu/hr		≥ 10.1 EER ≥ 10.4 IPLV ≥ 3.2 COP	11.5 EER 13.4 IPLV 4.0 COP
	Air-Source 136 – 240 MBtu/hr		≥ 9.3 EER ≥ 9.5 IPLV ≥ 3.1 COP	10.5 EER 12.4 IPLV 3.3 COP
	Water-Source[4] 65 – 135 MBtu/hr		≥ 12.8 EER ≥ 4.5 COP	14.5 EER 5.0 COP
ENERGY STAR Recommendations	Electric Air-Source < 65 MBtu/hr	Split Equipment	≥ 14.5 SEER ≥ 12 EER ≥ 8.2 HSPF	Not applicable
		Packaged Equipment	≥ 14 SEER ≥ 11 EER ≥ 8 HSPF	Not applicable

[1] Efficiency levels for air source units sized between 65 and 240 MBtu/hr meet ASHRAE 90.1-2007 minimum efficiency requirements.

[2] The best available EER and best available COP apply to different models.

[3] Only units with 3-phase power supply are covered in this category.

[4.] Water source heat pumps covered here use cooling towers and boilers as the heat transfer sink or source in a closed loop piping system. This may increase boiler energy use by lowering the return water temperature. Auxiliary pumping energy is not included in the water-source heat pump efficiency rating.

EER (Energy Efficiency Ratio) is the cooling capacity (in British Thermal Units per hour [Btu/hr]) of the unit divided by its electrical input (in Watts) at standard peak rating conditions. SEER (Seasonable Energy Efficiency Ratio) and IPLV (Integrated Part-Load Value) are similar to EER, but weigh performance during the cooling season.

COP (Coefficient of Performance) is the heating capacity (in Btu/hr) at standard heating conditions divided by its electrical input (also in Btu/hr). HSPF (Heating Seasonal Performance Factor), like SEER weighs heating performance at various conditions.

The FEMP commercial heat pump recommendations can be found at:
http://www1.eere.energy.gov/femp/procurement/eep_comm_heatpumps.html

The ENERGY STAR® small commercial, air-source heat pump recommendations can be found at:
http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_as_heat_pumps

Because the amount of refrigerant circulated through the heat pump loop is typically less during the heating season, accumulator(s) or storage reservoir(s) shall be provided to prevent compressor flooding. Thermostatic expansion valves may be substituted for storage only as approved by EPA.

If using heat pumps to condition multiple spaces, the duct design and register configurations may need to be adjusted in order to prevent formation and delivery of perceptible cool drafts to the heated spaces. In addition, in many areas of the U.S., it may be necessary to combine a separate, tempered outdoor air (OA) supply with the conditioned airstream generated from the heat pump. Alternatives to OA for tempering air including return air mixing or energy recovery from the return air.plit

6.5.4.1 Ductless Air-Source Heat Pumps

Green Seal GC-13 establishes environmental requirements for split ductless refrigeration (vapor compression), air-source unitary (single-stage) heat pumps, with maximum cooling capacity less than 65,000 Btu/hr and powered by a single-phase electric current. These systems are commonly referred to as split ductless heat pumps or "mini-splits." For split systems, the components shall be compatible and the following criteria apply to the matched components:

- Cooling efficiency
  - Minimum SEER of 12.0
  - Minimum COP of 3.5
- Heating efficiency
  - Minimum HSPF of 7.0
  - Minimum COP of 4.0.

6.5.4.2 Reverse Cycle Heat Pumps

Reverse cycle, air-source heat pumps (i.e., heat pumps used in air conditioning mode) shall meet the FEMP criteria listed in Table 6-8, and shall be sized and selected so as to minimize the need for supplementary cooling supply (i.e., DX or chilled water load). Where used for both space heating and cooling, the heat pump shall be sized based on the total cooling load requirement, and supplemental heating (e.g., natural gas or steam) shall be provided to achieve the balance point. Variable-speed compressors and/or fans shall be considered where technically feasible and where a significant potential for energy savings and life cycle cost savings exists. A check valve shall be provided for each expansion device in the refrigerant loop, such that the valve is in the appropriate upstream position depending on circulation direction (check valve OPEN/CLOSE shall be controlled by the BAS on a seasonal or user-programmed timing algorithm).

6.5.5 Ground Source (Geo-exchange) Heat Pumps

6.5.5.1 Designer Qualifications

Ground Source Heat Pumps (GSHPs) shall be designed by an individual who is a Certified Geo-exchange Designer and is regularly engaged in the design of the type and capacity of system(s) specified in this project for the immediate three years prior to the project award date. Certification as a Certified Geo-exchange Designer shall be kept up to date and maintained with the Association of Energy Engineers. The proposed System Designer must furnish documentation from the owner of each of at least three GSHP systems of similar size and complexity to the project in question, verifying that each system has performed in the manner intended for a minimum of 12 months without significant repairs or failures.

6.5.5.2 Energy Efficiency

All heat pump systems and components must be designed for energy efficiency and comply with applicable FEMP/ENERGY STAR® requirements. Components and systems must meet or exceed the performance criteria for FEMP/ENERGY STAR® with respect to the energy efficiency ratio (EER) and coefficient of performance (COP) presented in Table 6-8:

Table 6-8: FEMP Ground Source Heat Pump Efficiency Recommendations

Product Type	Recommended		Best Available[1]	
	EER[2]	COP[3]	EER[2]	COP[3]

Table 6-8: FEMP Ground Source Heat Pump Efficiency Recommendations

Product Type	Recommended		Best Available[1]	
	EER[2]	COP[3]	EER[2]	COP[3]
Closed Loop[5]	≥ 16.1 ≥ 17.1	≥ 3.5 ≥3.6	25.8	4.9
Open Loop[4,5]	≥ 18.2 ≥21.1	≥ 3.8 ≥4.1	31.1	5.5
Direct Expansion (DX)[6]	≥ 16	≥ 3.6	---	---

1. The best available coefficient of performance (COP) and best available energy efficiency ratio (EER) for the open-loop system apply to different models.
2. EER is the cooling capacity (in BTU/hour) of the unit divided by its electrical input (in Watts) at standard (ARI/ISO) conditions of 77°F entering water for closed-loop models and 59°F entering water for open-loop systems.
3. COP is the heating capacity (in BTU) of the unit divided by its electrical input (also in BTU) at standard (ARI/ISO) conditions of 32°F entering water for closed-loop models and 50°F entering water for open-loop equipment.
4. Open-loop heat pumps, as opposed to closed-loop models, utilize "once-through" water from a well, lake or stream.
5. Information from FEMP and ENERGY STAR® websites. The first values are effective January 1, 2011; the second values are effective January 1, 2012.
6. Information from ENERGY STAR® website. These values are effective January 11, 2011.

This information can also be found at the FEMP ground source heat pump recommendation website: http://www1.eere.energy.gov/femp/procurement/eep_groundsource_heatpumps.html

This information can also be found at the ENERGY STAR® geothermal heat pumps product criteria website: http://www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps

ARI – American Refrigeration Institute; ISO – International Organization for Standardization

As defined in §104 of EPAct 2005 and §434 of EISA 2007, a life cycle cost analysis of alternatives must be developed and considered in the selection of equipment or systems. In general, project managers should select the most energy efficient equipment/systems for which there are at least two products available for the designed capacity. The project HVAC engineer must provide the following data for equipment associated with the GSHP system:

- Design rated capacity
- Mechanical efficiency
- Noise ratings
- Motor speeds (including VFDs where installed)
- Electrical characteristics.

6.5.5.3 Standards for Water-Source GSHPs

For water-to-air applications that have ductwork to distribute hot or cold air and to provide humidity control, use ARI/ISO 13256-1 as the standard for the water-source heat pump. For water-to-water applications, such as in hydronic or circulating fluid systems, domestic water heating systems, or radiant heating systems, use AFI/ISO 13256-2 as the standard for water-source heat pumps. For projects where the water-to-water heat pump unit is used to provide a domestic hot water supply in addition to space conditioning, the IPC and/or other applicable local codes must be followed. To prevent cross-connection to, and cross-contamination of, the potable water supply from the refrigerant loop, consider using the following:

- A de-superheater (*check ASHRAE 90.1, Chapter 6 to determine whether heat recovery for service water heating is required*)
- A double-walled heat exchanger that is vented
- A secondary heat exchanger in the water circuit, such as a plate-and-frame heat exchanger.

6.5.5.4 System and Component Effective Lives

In general, GSHP systems and components shall be designed for an effective life of 25 years or longer. If it is not possible to obtain life cycle cost-effective systems or equipment with an expected life of at least 25 years, a life cycle cost-effective alternative may be used so long as the expected life is maximized and the rationale documented.

6.5.5.5 Maximum and Minimum Operational Temperatures

The maximum entering water temperature to the heat pump(s) under peak air conditioning load design condition should not exceed 95°F. The minimum entering water temperature to the heat pump(s) under the peak heating load design conditions should be no lower than 30°F.

6.5.5.6 Requirement for In-Situ Thermal Testing

For projects where the total heating design load for the GSHP system exceeds 480,000 BTU/hr or the total cooling design load exceeds 40 ton R, in-situ thermal properties testing must be conducted. In-situ thermal properties tests must be conducted in accordance with the procedures outlined in ASHRAE Item 90376-1997 (or most recent version), *Ground-Source Heat Pumps, Design of Geothermal Systems for Commercial and Industrial Buildings*.

6.5.5.7 Prohibition on Use of Chlorofluorocarbons (CFCs)

Consistent with §2(f) of EO 13423 and Guiding Principle V of the Federal Sustainable Buildings MOU, equipment using Class I CFCs (i.e., substances with an ozone depletion potential of 0.2 or greater) are not permitted. Equipment using Class II CFCs (i.e., ozone depletion potential between 0.05 and 0.2—often identified as hydro-chlorofluorocarbons [HCFCs])—are allowed, but are discouraged in favor of refrigerants that have ozone depletion potential less than 0.05, so long as they are life cycle cost-effective and do not have significant other deleterious effects. For example, a heat pump using HCFCs and a vapor compression cycle may be preferable to an ammonia absorption cycle heat pump, if large volumes of ammonia must be stored in tanks on site.

A prerequisite for EPA facilities to become LEED-NC 2009 certified is that they: (1) use no ozone-depleting refrigerants in new HVACR equipment; and (2) phase out/replace all ozone-depleting refrigerants in existing HVACR equipment within five years of completing renovations. In addition, facilities can earn one point if the aggregated life-cycle ozone depletion potential (LCODP) and life-cycle global warming potential (LCGWP) are below a threshold value (*formulas and instructions for calculating LCODP and LCGWP are provided in the LEED Reference Guide*).

6.5.5.8 Refrigerant-to-Water Heat Exchangers

The following requirements apply to all refrigerant-to-water heat exchangers installed as part of a GSHP system:

- The inlet water temperature range to the refrigerator-to-water heat exchanger for GSHPs nominally shall be 45°F to 90°F. "Extended range" heat pumps (25°F to 100°F) may be utilized where practicable

- Coaxial-type heat exchangers (tube-in-tube) shall be used. The inner tube shall be cupronickel (hardened copper-nickel alloy) construction, and the outer tube shall be of steel (mild steel or other acceptable steel) construction

- The refrigerant side of the heat exchanger shall be tested and rated for 450 psi, gauge (psig) working pressure. The water side of the heat exchanger shall be tested and rated for 400 psig working pressure

- A parallel capillary tube/thermal expansion valve assembly shall provide superheat over the entire liquid temperature range

- All refrigerant-to-water heat exchangers and refrigerant piping shall be insulated to prevent condensation on the piping containing low temperature water. Insulation shall conform with the relevant EPA CPGs (refer to Section 6.3.1).

6.5.5.9 Refrigerant-to-Air Heat Exchangers (DX Systems)

Refrigerant-to-air heat exchangers may be installed as component(s) of DX systems. Refrigerant-to-air heat exchangers shall be constructed from rifled copper tubes with plate aluminum fins and designed for a refrigerant working pressure of 450 psig. Fins shall be mechanically bonded to the tubes. The condensate drain pan shall be epoxy-coated and insulated and shall be equipped with overflow protection. The drain pan may be corrosion-resistant plastic, galvanized steel, or stainless steel, depending on project requirements.

6.5.5.10 De-superheaters

Service hot water de-superheaters shall be of vented, double-walled construction and shall be factory-assembled, -designed, -tested, and -rated. De-superheaters shall be UL-listed and shall be equipped with the following features:

- Factory-installed water pump powered by a sealed magnetic drive motor
- Water line thermostat
- Safety thermostat to prevent scalding
- Internal fuse
- Manual ON/OFF switch
- Low-refrigerant gas temperature limit switch
- Air bleed port
- Refrigerant ports.

6.5.5.11 Fans

Fans shall be centrifugal type, direct-drive units with permanently lubricated motors. Motors shall be ECMs, microprocessor-controlled, DC-type motors with factory-set internal programming for the specific unit, and featuring soft START/STOP and a DELAY OFF feature for maximum efficiency and quiet operation. The airflow delivered by the blower shall be adjustable by ±15 percent from the rated airflow.

6.5.5.12 Compressors

Compressors shall be hermetically-sealed and installed on vibration isolators in an acoustically treated enclosure. The compressor shall have the following features:

- High and low pressure switches
- Low suction temperature cut-out
- Motor thermal overload protection
- Five-minute anti-recycle timer
- Start capacitor kit.

The compressor shall be configured to enable lockout circuit reset at the remote thermostat and at the disconnect.

6.5.5.13 Bypass for Purging and Flushing

A bypass around the heat pump unit condenser coil shall be included and shall consist of isolation valves and piping that allow for purging and flushing of the system piping.

6.5.5.14 Controls

Controls and safety devices shall be factory-wired and mounted within the control box of the unit cabinet. The system shall include a microprocessor-based controller that communicates with an electronic, multi-stage space thermostat. The microprocessor shall control:

- Sequencing
- High- and low-pressure switch monitoring
- Freeze protection
- Lockout control
- Night setback
- Emergency shutdown
- Short cycle protection
- Random start
- Light-emitting diode (LED) mode and fault indicators
- Fault memory
- Input and output diagnostics

- Communications port.

The system shall also include a factory-installed, low-voltage terminal block (for field control wiring) and a low voltage transformer. Communications capability for remote DDC and connection to the BAS shall be provided and use standard communications protocol such as LonWorks or BACnet (refer to Chapter 8 of this Manual). The heat pump manufacturer shall provide a hand-held, remote services terminal capable of interfacing with the microprocessor controller to perform diagnostics, data retrieval, and calibration functions.

6.5.5.15 Installer Qualifications

The GSHP installer must be accredited by the International Ground Source Heat Pump Association (IGSHPA). The proposed Installer must furnish documentation from the owners of at least three operating GSHP systems, of similar size and complexity to the project in question, verifying that each system has performed in the manner intended for a minimum of 12 months without significant repairs or failures. The Well Driller must be a licensed well driller in the particular state or territory where the work occurs. Ground heat exchange fabricators must have completed a heat fusion training program in which each participant has performed heat fusion procedures under the direct supervision of an IGSHPA Certified Heat Fusion Technician. Certified pipe fusion technicians must attend a retraining school at least every three years, and single failure of a fusion joint will void the certification and require retesting.

6.5.5.16 Ground Heat Exchanger Materials

Acceptable pipe materials for the underground portion of the ground heat exchanger are PE and polybutylene (PB). Specifications for PE pipe are as follows:

- All pipe and heat-fused materials shall be manufactured from a virgin PE extrusion compound material, in accordance with ASTM D2513, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings.* Pipes shall be manufactured to outside diameters, wall thickness, and respective tolerances as specified in:

  - ASTM D3035, *Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter*

  - ASTM D2447, *Standard Specification for PE Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter*

  - ASTM F714, *Standard Specification for PE Plastic Pipe (SDR-PR) Based on Outside Diameter.*

- The material shall maintain a 1,600-psi hydrostatic design basis at 73.4°F per ASTM D2837, and shall be listed in Plastic Pipe Institute TR4 as a PE3408 piping formulation. The material shall be a high-density polyethylene extrusion having a cell classification of PE345434C or PE355434C with a UV stabilizer of C, D, or E, as specified in ASTM D3350, with the following exception—this material shall exhibit zero failures (F0) when tested for 192 or more hours under ASTM D1693, Condition C.

- Pipe with a diameter less than 1.25 inches (nominal) shall be manufactured in accordance with ASTM D3035, with a dimension ration of 11. Pipe manufactured with a diameter greater than 1.25 inches (nominal) shall be manufactured in accordance with ASTM D3035 (minimum dimension ratio of 13.5) or ASTM D2447 (Schedule 40). If the pipe is used in a vertical bore application of over 200 feet in depth, it shall be manufactured in accordance with ASTM D3035, with a dimension ratio of 11. Pipe with a diameter of 3 inches (nominal) or greater shall be manufactured in accordance with ASTM D3035, ASTM D2447, or ASTM F714, with a minimum dimension ratio of 17.

Specifications for PB pipe are as follows:

- All pipe and heat fusion material shall be manufactured from a virgin PB extrusion compound material that conforms to the requirements for Type II, Grade 1, Class B or C, as specified in ASTM D2581.

- Pipe with a diameter of 2 inches (nominal) or less shall be manufactured in accordance with ASTM D2666, with a dimension ratio of 13.5. If the pipe is to be used in a vertical bore application of over 200 feet in depth, it shall be manufactured in accordance with ASTM D3035, with a dimension ratio of 11. Pipe with a diameter of 2 inches (nominal) or greater shall be manufactured in accordance with ASTM D3000 with a dimension ratio of 11. Note that ASTM D2666 and D3000 have been withdrawn by ASTM. The Installer may propose similar standards or requirements for the GSHP project.

6.5.5.17 Pipe Joining Methods

The only acceptable method for joining buried pipe systems is by a heat fusion process. PE pipe shall be butt- or socket-fused, in accordance with the pipe manufacturer's recommended procedures. PB pipe shall be socket-fused, in accordance with the pipe manufacturer's recommended procedures. Fused transition fittings with reinforced threads must be used to adapt the copper or high-strength hose connections to the circulating pump and heat pump. Barbed fittings are not permitted.

6.5.5.18 Flushing, Purging, and Pressure- and Flow-Testing

All fusion joints and loop lengths must be checked to verify that no leaks have occurred due to the fusion joining process or to shipping damage. All loops must be pressure-tested before installation, and all horizontal components of the ground heat exchanger must be pressure-tested prior to backfilling. Heat exchangers must be tested hydrostatically at the smaller of 150 percent of the pipe design rating or 300 percent of the system's design operating pressure. No leaks shall occur within a 30-minute period. Flow rates and pressure drops must be compared to calculated design values to ensure that no blockage or kinking of pipe is occurring. During air pressure testing, a minimum velocity of 2 fps must be maintained in each piping section for a minimum of 15 minutes to remove all air. A change of greater than 1 inch in the level of fluid inside the purge pump tank during pressurization indicates that air is still trapped inside the system.

6.5.5.19 Pipe Placement and Backfilling

The following requirements will apply for horizontal piping systems:

- Sharp bending of pipe around trench corners must be prevented by using a shovel to round the corners. Follow applicable manufacturer's recommendations.

- Any sharp-edged rocks must be removed prior to backfilling to avoid potential damage to the pipe. Use the IGSHPA's "Slinky" backfilling procedures to ensure elimination of air pockets around the pipes.

- Return bends in narrow trenches must be partially backfilled by hand to properly support the pipes and prevent kinking.

- All buried GSHP pipes in systems containing antifreeze that pass parallel within 5 feet of any wall, structure, or water pipe must be insulated with minimum R2 closed-cell insulation.

Vertical boreholes must be backfilled to ensure adequate heat transfer between the ground and the working fluid within the exchanger. Applicable local and state codes for backfilling boreholes must be followed. Detailed grouting procedures are also specified in the IGSHPA's *Grouting Procedures Manual.*

For pond and lake loop systems, the GSHP manufacturer's recommended procedures must be followed.

6.5.6 Unit Heaters and Radiant Heating Devices

Radiant heating systems (circulating hot water or gas-fired) may be overhead or under-floor type. They may be considered in lieu of convective or all-air heating systems in areas that experience infiltration loads in excess of two air changes per hour at design heating conditions. Radiant heating systems may also be considered for high bay spaces and loading docks.

Conventional electric or gas-fired unit heaters may be installed in industrial areas (e.g., loading docks, machine shops) where other modes of heating are impractical. However, unit heaters shall not be used to heat large, open areas or areas where clusters of unit heaters would be required, because these configurations would likely be less energy-efficient than other alternatives (e.g., radiant heating).

6.5.7 Solar Heating Systems

Active solar heating systems use similar components and have a similar configuration to solar hot water systems (refer to Section 6.7.4). Instead of heating supply water directly, the solar collectors heat the working fluid (i.e., water or a solution of water and antifreeze) that then:

EPA facilities can earn points toward LEED-NC 2009 certification for using certain types of on-site renewable energy systems to offset building energy costs. Solar heating systems that transfer thermal energy using collection panels; and include pumps and/or fans and hot water storage tanks are eligible for this Credit.

- Circulates through a hydronic system, with radiators and/or floor coils for heat release to the conditioned space, or
- Heats air in the return duct, which is then recycled into a forced air distribution system.

Selection of either method shall be dictated by facility-specific requirements and EPA preferences.

The remainder of this section summarizes key requirements for solar heating systems. For additional in-depth information, refer to the following publications:

- U.S. DoD, *Unified Facilities Criteria, Solar Heating of Buildings and Domestic Hot Water*, UFC 3-440-04N
- Brockman, K., *Solar Water Heating System Requirements*, Energy Trust of Oregon, Inc., V23.

Also refer to Section 6.7.4 regarding solar heating systems for producing domestic hot water. Systems designed to provide solar thermal space heating should, wherever possible, be connected with the domestic hot water system and capable of supplying some or all of a facility's hot water requirements.

6.5.7.1 Design Calculations

The tilt orientation of space heating solar collectors shall be estimated as the site latitude plus 15 degrees—this will have the greatest probability of optimal collector alignment during the heating season (optimal alignment being the sun's rays perpendicular to the collector surface). The number of collectors shall be calculated as the required heat load divided by the rated heat output of each collector (*note that the "required" heat load is the load that the facility is depending on solar energy to supply, which may be less than 100 percent*). For forced-fluid circulation systems (the most common system configuration), the recommended range of flow rates is 0.015 gallons per minute per square foot (gpm/ft^2) – 0.04 (gpm/ft^2) of solar collector area.

6.5.7.2 Collectors

All solar collectors must have an OG-100 certification issued by the Solar Rating and Certification Corporation. If mounted on a roof, the roof shall be evaluated for the excess static, wind, snow, and seismic loads (as applicable) that will result, and the roof shall be reinforced as necessary. Collectors shall generally be mounted at least 1.5 inches above the roof surface and properly flashed to the roof, as required. All roof penetrations must be made watertight following installation of the collectors.

To allow the working fluid to completely drain from the collectors and piping exposed to freezing conditions back into the system reservoir tank, the collectors shall be pitched a minimum ⅛ inch per foot to the inlet. In addition, the piping shall be pitched between the collector and the drain-back reservoir a minimum ⅛ inch per foot. To ensure that air does not become trapped in the collector loop piping (which can cause the pump to cavitate and prematurely fail), there shall be no inverted U-loop piping configurations between the storage tank and the pump.

6.5.7.3 Plumbing

All piping in the solar heating system shall be copper or cross-linked polyethylene (PEX), and all fitting shall be either copper or brass. Where used, PEX piping connections shall be installed with compression fittings. PEX pipe is rated only to 180°F and therefore is not acceptable for collector loop piping.

To ensure correct system operation, and to preserve the integrity of joint seals, piping runs shall be adequately supported using appropriate materials. Table 6-9 indicates the maximum spacing between supports for different piping types:

Table 6-9: Maximum Spacing Between Supports, Solar Heating Systems

Pipe Type	Run Type	Maximum Spacing (ft)
Rigid Copper	Horizontal	6
	Vertical	6
Flexible Copper	Horizontal	6
	Vertical	6
PE or PEX	Horizontal	4
	Vertical	4

Table 6-9: Maximum Spacing Between Supports, Solar Heating Systems

Pipe Type	Run Type	Maximum Spacing (ft)

Source: Brockman, K., 2008, *Solar Water Heating Systems Requirements*, EnergyTrust of Oregon, Inc., V23, April.
PE – polyethylene; PEX – cross-linked polyethylene; ft – feet

High temperature-rated, closed-cell, elastomeric foam or factory-jacketed molded fibrous glass pipe insulation with a minimum ¾-inch wall thickness and R-12 rating shall be installed on all system piping with exposure to outdoor conditions. To ensure integrity of the insulation, applicable minimum temperature ratings for insulation, by system service, are as follows:

- System collector loop: 220°F
- All other piping: 180°F.

Insulated pipe shall be protected from UV degradation and weather by wrapping it with UV-inhibited acrylonitrile butadiene styrene (ABS), aluminum pipe, or aluminum jacketing. PVC piping shall not be used. Joints shall be completely sealed and shall shed snow, rain water, or other moisture. Continuous, overlapped wrapping with adhesive-backed aluminum or UV-inhibited tape is allowed where approved by EPA.

To avoid potentially damaging pressure buildup from thermal expansion of water in the heated water loop (and resulting unwarranted discharge of temperature and pressure relief valves), a properly-sized expansion tank shall be installed. The expansion tank shall be sized based on the manufacturer's recommendations and/or the ASHRAE *Handbook—HVACR Systems and Equipment.* The air charge pressure in the expansion tank shall be adjusted to match the inlet water supply pressure before installation. The expansion tank shall be located either:

- Between the solar energy storage tank (solar tank) and backup water heater; or
- Upstream from the solar tank and downstream from any pressure-reducing valve(s), check valve(s), or backflow preventer(s) in the cold water supply line.

6.5.7.4 Circulation Pump

To ensure that the pump shaft is continuously immersed in and lubricated with collector working fluid (which will aid in prolonging the useful life of the pump), the circulation point shall, where feasible, be installed with the shaft oriented horizontally. Isolation features (e.g., unions, ball valves) shall be included to enable servicing and/or replacement of the pump. To ensure correct system operation, the pump differential controller shall activate the circulation pump at a 5°F to 10°F differential between the solar storage tank and the collectors, and it shall deactivate the pump at a 4°F to 6°F differential. The controller shall also have a maximum 180°F high-limit setting, and the controller sensors shall be pre-tested for accuracy. To allow for monitoring and diagnostic servicing, the controller shall be mounted (where possible) within 6 feet of the solar tank and hard-wired through rigid conduit to the nearest power source.

6.5.7.5 Solar Tank

The purpose of the solar tank is to act as a reservoir for heat energy during nighttime and periods of inclement or cloudy weather. The solar tank's volumetric capacity shall be 1.75 gallons per square foot (gal/ft^2) of net solar collector area or greater. To reduce heat loss, any solar tank installed on a concrete floor must be on an R-10 (minimum) pad of high-density foam designed for use under water heaters.

To ensure safe relief of solar pre-heated water in the event of over-heating, a relief valve shall be installed per local plumbing code requirements. The relief valve shall be engineered and specified according to the requirements of the particular tank. Small systems, i.e., those typically associated with light commercial applications, require a 210°F and 150 psig valve.

An anti-convective plumbing loop or trap, connected with sweat fittings or brass unions, shall be installed to inhibit hot water migration through the cold water supply piping to the solar tank. This loop or trap shall be located in proximity to the solar tank and have a minimum 8-inch vertical drop to constitute an effective convection heat barrier. Heat trap nipples alone are not reliable for stopping heat migration and will not meet this specification. The use of flexible copper pipe connectors with threaded fittings is permitted only if gaskets meet the high temperature requirements of the system.

All solar thermal storage and auxiliary tanks and related components shall be located in a totally enclosed, “tempered,” and weatherproof space, such as:

- An interior heated space
- A fully-enclosed, weatherproof space that is continually warmed to above freezing temperatures during the winter
- A detached, fully-enclosed exterior space with adequate supplemental heat
- A fully-enclosed basement under a heated, occupied space with a concrete floor and below-grade walls, and not subject to outdoor ambient air flow
- A fully-enclosed and insulated structure located in a vented crawl space under the insulated floor of a heated, occupied space
- A fully outdoor shed attached to a common wall with a heated space that is weatherproof and equipped with an R-19 (minimum) insulated walls and roof and a concrete floor (or wood floor insulated to R-19 minimum).

If the solar tank is located in a space where water leakage could cause structural damage, a drip pan with a pipe routed to a drain or to the outside must be installed.

6.5.7.6 Freeze Protection

The system shall incorporate freeze and over-heat protection strategies that:

- Require no manual operations on the part of the occupants
- Result in negligible electrical energy losses due to recirculation of heated water during cold winter conditions
- Result in negligible electrical energy losses due to draining of heated water
- Possess demonstrated or theoretical reliability in weather conditions at the project site.

To prevent cross-contamination between the working fluid loop and heated water loop, a vented, double-walled heat exchanger shall be installed. The vent shall be designed to reveal fluid leakage upon failure of the heat exchanger wall(s), thus indicating the need for replacement. A mixture of high-temperature rated propylene glycol (antifreeze) mixed with distilled water shall be used as the working fluid, and the volume percentages of antifreeze shall be as indicated in Table 6-10:

Table 6-10: Volume Percentages of Antifreeze for Working Fluid, Solar Heating System

Design Outdoor Temperature (°F)	Volume % of Antifreeze Required
-60	64%
-50	61%
-40	57%
-30	53%
-20	49%
-10	45%
0	38%
10	31%
20	20%

However, the volume percentages of antifreeze shown in Table 6-10 shall not be exceeded by greater than 5 percent, because the resulting mixture's increased heat capacity will reduce heat transfer efficiency to the water loop.

6.5.7.7 Valves

To ensure that the system can be isolated from the backup or auxiliary heating system(s) in an emergency, for servicing, or component replacement, fully-ported values shall be installed to enable bypass of the entire solar heating system. Brass ball valves shall be used, unless otherwise approved by EPA. Valves shall comply with SRCC OG-300, *Solar Water Heating Design and Installation Guidelines* and shall be installed at various points within the system to enable filling/refilling, flushing, and draining both the working fluid (antifreeze/water) loop and the heated water loop.

To minimize nighttime convective heat loss from heated water in the solar tank, a check valve shall be installed on the return line of the collector working fluid loop, immediately upstream from the collectors.

6.5.7.8 Instrumentation

To monitor the fluid flow rate in the system, a flow meter shall be installed in the vertical piping to the collector(s), in an easily visible location and shall be connected to the BAS. To monitor temperature of the solar pre-heated water, a thermometer or thermocouple shall be installed at the hot water outlet port of the solar tank, in an easily visible location. A digital temperature readout and connection to the BAS shall be provided

6.5.7.9 Forced Air Heating Systems with Solar Heat Source

Heated working fluid shall be pumped directly from the solar collectors (or from a storage tank) through a coil located in the return duct of the air distribution system. An auxiliary source of heat (e.g., a boiler) shall be provided in case the solar heating system cannot accommodate the total heating load of the building.

6.5.7.10 Hydronic Heating Systems with Solar Heat Source

The operating temperature at the point of delivery (i.e., radiators) shall be 140°F or higher. However, for radiant floors the temperature shall not exceed 80°F for safety and occupant comfort reasons.

6.5.8 Boiler Feed Water Pumps and Metering

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. The feed 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 pre-set to lift at a lower pressure than the boiler safety valve setting plus static and friction heads. Boiler feed water pumps shall generally be sized and selected in accordance with the guidelines presented in Section 6.5.2 for boiler hot water pumps.

Each boiler feed pump (or the combined header if approved by EPA) shall be equipped with a magnehelic flow meter with totalizer. A disc, compound, or turbine meter may be substituted on piping less than 3 inches diameter, with EPA's approval. The meter shall be capable of indicating instantaneous flow and total water consumption in cubic feet and gallons, and shall be provided with a digital local display. The meter shall also have the capability to log data at minimum 15-minute intervals, and transmit the data to the BAS for subsequent trend computations and analysis.

6.5.9 Fire Protection for Central Heating Equipment

Furnaces and boilers for central heating systems shall be enclosed in a room with 2-hour fired-rated walls, floors, and ceilings. Openings shall be protected by automatic or self-closing fire doors. For small units consisting of a single furnace operating a hot air system or a boiler not exceeding 15 psig or a rating of 10 bhp, a 1-hour fire-rated enclosure is permissible. Where local codes are more stringent, the local codes shall govern.

For large-capacity gas services (piping greater than 3-inch diameter at 4 in WC pressure head or any other size with equivalent or greater delivery capabilities) within a building, the piping shall be enclosed in fire-resistant 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.

6.5.10 Process Heating

Process heating shall be supplied via centrally distributed steam or hot water. Electrical resistance heaters shall not be used unless powered by a reliable renewable energy source. Process heating for laboratories shall be supplied on a modular basis, with the ability to be activated/deactivated or shunted in response to anticipated changes in laboratory operations and corresponding demands.

6.6 Cooling Systems

6.6.1 Chilled Water Distribution Piping

Chilled water piping shall be designed and installed in accordance with the general requirements outlined in Section 6.10. In addition, the following specific requirements shall apply:

- Chilled water pipe shall be black iron or carbon steel pipe or hard copper tubing. Standard wall steel pipe or Type L hard copper pipe will be satisfactory for most applications; however, the piping material selected shall be checked for design temperature and pressure ratings

- Chiller water piping shall be insulated to reduce heat gain from the surrounding environment. The maximum allowable conductive heat transfer coefficient shall be 0.17 Btu-inch/hr/ft^2-°F) at 75°F mean temperature in accordance with ASTM C177-2004. The minimum thickness of insulation shall be 1.5 inches for pipes less than 3 inches diameter and 2 inches for pipes greater than 3 inches diameter

- Fittings shall be:

  - For steel pipe, welded, galvanized, cast, malleable, or black iron. (*Standard 125 lb cast iron or 150 lb malleable iron fittings will be satisfactory for most applications; however, the fitting material selected shall be checked for temperature and pressure ratings*.)

  - For copper pipe, cast brass, wrought copper, or wrought brass

- For cooling coil arrangements, multiple rows of coils may be required to achieve satisfactory humidity control

- Expansion tanks are required on all chilled water piping networks to manage temperature-dependant changes in water volume

- Pipes shall be marked in accordance with ASME AB.1-1996 and Chapter 5 of the GSA's *Facilities Standards for the Public Buildings Service*, Publication P-100.

6.6.2 Pumps

Pumps for chilled water shall generally be sized and selected in accordance with the guidelines contained in Section 6.5.2 for boiler hot water pumps. It is important to note that the life-cycle costs of chilled water pumping are heavily interdependent with other cooling system parameters, such as:

- Pipe sizes

- Chiller capacities

- Condenser water leaving temperature

- Cooling tower sizing.

Therefore, the model utilized to perform the LCAA must evaluate the entire cooling system and allow for sensitivity evaluations on all of the above parameters (i.e., not just pump sizes) in order to identify the most cost-effective and feasible pumping alternative.

6.6.3 Vapor Compression Chillers

The selection of centrifugal, reciprocating, helical, rotary-screw, absorption, or steam-powered chillers shall be based on COPs under full-load and part-load conditions. A complete LCCA shall be performed, and system performance shall be estimated based on these COPs and other pertinent factors. The LCCA shall also consider the pumping energy burdens on the chilled water and condenser water system as part of the evaluation.

6.6.3.1 Efficiency Ratings

FEMP minimum requirements for chillers are contained in Tables 6-11 and 6-12. Cooling systems with a refrigeration capacity less than 50 ton R shall use air-cooled chillers. In addition, centrifugal or screw chillers shall be specified for applications greater than 120 ton R, unless otherwise approved by EPA.

Table 6-11: FEMP Air-Cooled Chiller Efficiency Recommendation[1]

Compressor Type and Capacity		Recommended[2] IPLV[3] (kW/ton R)	Best Available[2] IPLV[3] (kW/ton R)
Part-Load Optimized Chillers	Scroll (30 – 60 ton R)	≤ 0.86	0.83
	Reciprocating (30 – 150 ton R)	≤ 0.90	0.80
	Screw (70 – 200 ton R)	≤ 0.98	0.83
Full-Load Optimized Chillers	Scroll (30 – 60 ton R)	≤ 1.23	1.10
	Reciprocating (30 – 150 ton R)	≤ 1.23	1.00
	Screw (70 – 200 ton R)	≤ 1.23	0.94

1. Depending on the application, buyers should specify chiller efficiency using either full-load or integrated part-load values.
2. Values are based on standard rating conditions specified in ARI Standard 550/590-1998, *Standard for Water Chilling Packages Using the Vapor-Compression Cycle*. Only packaged chillers (i.e., none with remote condensers) are covered.
3. Integrated part-load value (IPLV) is a weighted average of efficiency measurements at various part-load conditions, as described in ARI Standard 550/590-98. These weightings have changed substantially from the previous standard, ARI 590-92, lowering IPLV ratings by 10%-15% for the same equipment.

This information can also be found at the FEMP air-cooled chiller recommendation website: http://www1.eere.energy.gov/femp/procurement/eep_ac_chillers.html

There is no ENERGY STAR recommendation for this product.

kW – kilowatts; ARI – American Refrigeration Institute; ton R – tons of refrigeration (1 ton R = 12,000 BTUs)

Table 6-12: FEMP Water-Cooled Chiller Efficiency Recommendation[1]

Compressor Type and Capacity		Recommended[2] IPLV[3] (kW/ton R)	Best Available[2] IPLV[3] (kW/ton R)
Part-Load Optimized Chillers	Centrifugal (150 – 299 ton R)	≤ 0.52	0.47
	Centrifugal (300 – 2,000 ton R)	≤ 0.45	0.38
	Rotary Screw ≥ 150 ton R	≤ 0.49	0.46
Full-Load[4] Optimized Chillers	Centrifugal (150 – 299 ton R)	≤ 0.59	0.50
	Centrifugal (300 – 2,000 ton R)	≤ 0.56	0.47
	Rotary Screw ≥ 150 ton R	≤ 0.64	0.58

1. Depending on the application, buyers should specify chiller efficiency using either full-load or integrated part-load values.
2. Values are based on standard rating conditions specified in ARI Standard 550/590-1998, *Standard for Water Chilling Packages Using the Vapor-Compression Cycle*. Only packaged chillers (i.e., none with remote condensers) are covered.
3. Integrated part-load value (IPLV) is a weighted average of efficiency measurements at various part-load conditions, as described in ARI Standard 550/590-1998. These weightings have changed substantially from the previous standard, ARI 590-1992, lowering IPLV ratings by 10%-15% for the same equipment.
4. Full-load efficiency is measured at peak load conditions described in ARI Standard 550/590-1998.

This information can also be found at the FEMP air-cooled chiller recommendation website: http://www1.eere.energy.gov/femp/procurement/eep_wc_chillers.html

There is no ENERGY STAR recommendation for this product.

ARI – American Refrigeration Institute; kW – kilowatt; ton R – tons of refrigeration (1 ton R = 12,000 BTUs)

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.

6.6.3.2 Capacity Modulation

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.

6.6.3.3 Motors

Compressor motors for refrigeration equipment shall be selected in compliance with all requirements of NFPA 70.

6.6.3.4 Evaporators

Liquid coolers (evaporators) shall be designed to meet the design pressure, material, welding, testing, and relief requirements of ASHRAE Standard 15 and the ASME Boiler and Pressure Vessel Code, Section VIII. Furthermore, evaporators shall be selected according to the recommendations of the ASHRAE 2008 *Handbook—HVAC Systems and Equipment.*

6.6.3.5 Chiller Plant Sizing

Chiller plants shall be sized depending on the specific needs of the project. Where feasible, EPA's preference is for multiple, modular units that provide maximum part-load efficiency/turn-down capacity in a life cycle cost-effective manner. Chiller plants shall also be designed to accommodate potential expansion of the facility's total load (i.e., by adding new, modular chillers).

During the design process, consideration shall be directed toward installation of modular chiller plants. For example, the modular approach can help designers match loads effectively using a rotary-screw compressor and a centrifugal compressor instead of two centrifugal compressors; a reciprocating chiller could also be part of the energy-efficient module, combined with a screw compressor or a centrifugal compressor. In general, reciprocating chillers can serve the smallest loads efficiently, rotary-screw chillers are the most flexible, and centrifugal chillers are most efficient when fully loaded. Typical kW/ton profiles must be identified for the loads identified and temperatures required.

Consideration shall be given to using two chillers of unequal size instead of two chillers of equal size, which allows more flexibility in matching loads.] In this configuration, the smallest chiller can efficiently meet light loads (e.g., to keep process cooling equipment operating during the heating or temperate seasons). The additional chillers are staged to meet higher loads after the lead chiller (which may vary depending on the season) is operating close to full capacity. If an existing chiller operates frequently at part-load conditions, it may be cost-effective to replace it with multiple chillers staged to optimally match the demand profile of the facility.

Modular, packaged chillers can be especially useful in laboratory settings. A common problem in laboratory designs is the need to condition large volumes of incoming air to meet air change and exhaust requirements. Packaged chillers can assist in "balancing" the cooling load, as follows. Laboratory processes can be consolidated such that high cooling-load operations are concentrated in one area. Dedicated chiller(s) can then be installed to service this area, allowing the central heating plant chiller to be appropriately sized and precluding costly cooling energy from being "wasted" (as it would be if the central chiller[s] were over-sized).

6.6.3.6 Refrigerants

Chiller design must comply with the Clean Air Act Amendments of 1990 (CAAA), Title VI: *Stratospheric Ozone Protection* and 40 Code of Federal Regulations (CFR) Part 82: *Protection of Stratospheric Ozone*. CFC refrigerants are not permitted in new chillers. Commonly-used refrigerants such as HCFC-22, HCFC-123, HFC-134a, and HFC-410a are currently acceptable, although phase-out schedules must be followed. Chillers must be equipped with isolation valves, fittings, and service apertures as appropriate for refrigerant recovery during servicing and repair, as required by Section 608 of the CAAA. Chillers must also be easily accessible for internal inspections and cleaning.

A prerequisite for EPA facilities to become LEED-NC 2009 certified is that they: (1) use no ozone-depleting refrigerants in new HVACR equipment; and (2) phase out/replace all ozone-depleting refrigerants in existing HVACR equipment within five years of completing renovations. In addition, facilities can earn one point toward LEED-NC 2009 certification if the aggregated life-cycle ozone depletion potential (LCODP) and life-cycle global warming potential (LCGWP) are below a threshold value (formulas and instructions for calculating LCODP and LCGWP are provided in the LEED Reference Guide).

6.6.3.7 Controls

Chiller 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.

BACnet or LONWORKS (or equivalent) microprocessor-based controls shall be used. Chiller staging controls shall be capable of DDC communication and operability with the BAS. The control panel shall have self-diagnostic capability, integral safety control, and set point reset capability.

6.6.3.8 Valving

All units shall have adequate valves to provide isolation of an off-line unit without interruption of service. Chillers shall be piped to a common chilled water header with provisions to sequence chillers on-line to match the load requirements. All required auxiliaries for the chiller systems shall be provided with expansion tanks, heat exchangers, water treatment, and air separators, as required. If multiple chillers are used, automatic shutoff valves shall be provided for each chiller. Chiller condenser piping shall be equipped with recirculation/bypass control valves to maintain incoming condenser water temperature within the chiller manufacturer’s minimum recommended range. Part-load efficiency must be specified in accordance with ARI Standard 550/590.

6.6.4 Absorption Chillers

In any refrigeration system, work must be performed to drive the system to a higher energy state (e.g., higher pressures), in order to transfer heat away from a building space through an evaporation process. In a standard, electrically-driven chiller, this work is produced by a centrifugal or screw compressor. The refrigerant (formerly a pure CFC, now usually an HCFC) is compressed, then condensed, throttled, and evaporated—the evaporator being the device that removes heat from the space (or from a chilled water loop used to cool the space). In an absorption cooling system, the mechanical compressor in the standard vapor compression cycle is replaced by a “thermal compressor,” which uses the thermodynamics of a mixture (consisting of a refrigerant and an absorbent) and (paradoxically) application of heat energy to remove heat from the space.

The most common absorption cycles in use today use water as the refrigerant and lithium-bromide as the absorbent. Older units used ammonia as the refrigerant and water as the absorbent; the toxic properties of ammonia and corresponding EPA emergency planning requirements have resulted in more widespread use of the water-lithium bromide cycle.

Absorption chillers may be advantageous at facilities where year-round operation of steam or high temperature hot water boilers is required. Unused heat energy from boilers may be used to drive the generator section of an absorption chiller(s).

Minimum full- and part-load ratings for absorption chillers are contained in Table 6-13:

Table 6-13: Minimum Full-Load and Part-Load Ratings for Absorption Chillers[1]

Chiller Type	Full-Load			Part-Load		
	COP	EER	kW/ton R	COP	EER	kW/ton R
Air-Cooled, Single-Effect	0.60	2.05	5.86	NA	NA	NA
Water-Cooled, Single-Effect	0.70	2.39	5.02	NA	NA	NA
Double-Effect, Indirect-Fired	1.00	3.41	3.52	1.05	3.58	3.35
Double-Effect, Direct-Fired	1.00	3.41	3.52	1.00	3.41	3.52

1. Source: ASHRAE 90.1-2007. Ratings are identical for all chiller capacities. Required test procedure is as specified in ARI 560, *Absorption Water Chilling and Water Heating Packages*.

COP – Coefficient of Performance; EER – Energy Efficiency Ratio; kW/ton R – kilowatts per ton of refrigeration; NA – not applicable; ASHRAE – American Society of Heating, Refrigeration, and Air Conditioning Engineers; ARI – American Refrigeration Institute

Absorption chillers shall include the following components, at a minimum:

- Absorber, evaporator, and condenser
- First-stage generator (also second- and third-stage generators for double- and triple-effect machines, respectively)
- Refrigerant, absorber, and corrosion inhibitor solutions
- Low and/or high temperature heat exchangers
- Self-contained, hermetically-sealed, self-lubricating, water-cooled refrigerant and solution pumps (pumps shall be direct-coupled with the motor and be equipped with isolation valves)
- Anti-crystallization or automatic de-crystallization system
- Exhaust gas economizer, where applicable
- Controls package and wiring to master connection points
- Refrigerant spray nozzles
- Thermometers and sight glasses to allow visual inspection of unit operation.

6.6.4.1 Absorber, Evaporator, Condenser, and Generator

The absorption unit shall be of the shell-and-tube type construction, which shall be designed, constructed, tested, and certified in accordance with the ASME BPVC, Section VIII, Item D1. The absorber, evaporator, and condenser shall be suitable for not less than 150 psig to 250 psig working pressure (depending on the application).

The absorption unit may be enclosed in one or two shells with removable water boxes or heads. Condenser tubes shall be seamless copper or copper-nickel. Generator tubes shall be seamless copper-nickel. Absorber and evaporator tubes shall be either seamless copper or seamless copper-nickel. Tube ends shall be rolled into, or silver-brazed to, tube sheets. All copper or copper-nickel tubes shall be in accordance with ASTM B395/B395M.

For double-effect absorption chillers, the first-stage concentrator tubes shall be titanium, and the steam circuit shall comply with ASME BPVC, Section VIII, Item D1. Double-effect absorption chillers shall be equipped with capacity modulation to control solution flow entering and leaving the first stage concentrators.

The equipment specified shall have sufficient clearance between tubes and an adequate number of support sheets, with tubes fitted in the sheets, to prevent chafing of tubes or crevice corrosion due to uneven tube expansion, vibration, or pulsation. Holes in the tube sheets shall not have sharp corners. Each tube shall be removable, in one piece, from the support sheets through hole(s) individually provided for that tube. Water velocities through the cooler, condenser, and absorber tubes shall range from 3 fps (or less) to 12 fps. Consider double-bundle condensers in situations where hot water demand makes this option economically feasible.

Because absorption chillers do not use ozone-depleting refrigerants, substitution of these chillers for vapor-compression chillers can assist an EPA facility in: (1) meeting the Fundamental Refrigerant Management Prerequisite; and (2) obtaining points toward LEED-NC 2009 certification for minimization or elimination of ozone-depleting refrigerants.

6.6.4.2 Refrigerant and Absorber

Unless otherwise approved by EPA, refrigerants shall be distilled or de-ionized water, and the absorbent shall be lithium bromide. The refrigerant and any corrosion inhibitors used shall not generate films that would reduce machine efficiency by coating the tubes. The corrosion inhibitor shall not cause the solution to be classified as hazardous waste under the Resource Conservation and Recovery Act (RCRA).

6.6.4.3 Controls Package

The chiller shall be provided with a factory-mounted, pre-wired, microprocessor-based control system. The controls package shall provide operating controls, monitoring capabilities, programmable set points, safety controls, and BAS interface. Absorption chillers 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.

6.6.4.4 Factory-Applied Insulation

The chiller shall be provided with factory-installed insulation on surfaces subject to sweating, including the water cooler, suction line piping, economizer, and cooling lines. Insulation on heads of coolers may be field-applied; however, it shall be installed to facilitate easy removal and replacement of heads without damage to the insulation.

At a minimum, factory-insulated items installed indoors shall have a flame spread index no higher than 75 and a smoke developed index no higher than 150. Factory-insulated items (no jacket) installed indoors and located in air plenums, ceiling spaces, and attic spaces shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Flame spread and smoke developed indexes shall be determined by ASTM E84.

Insulation shall be tested in the same density and installed thickness as the material to be used in the actual construction. Material supplied by a manufacturer with a jacket shall be tested as a composite material. Jackets, facings, and adhesives shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50, when tested in accordance with ASTM E84. Refer to Chapter 9 of this Manual for any additional fire-proofing requirements.

6.6.4.5 Cooling Tower

Cooling tower(s) for heat rejection from the absorption chiller condenser loop shall be provided and installed in accordance with Section 6.6.8 of this Manual.

6.6.5 Energy Recovery from Chillers and Refrigeration Equipment

There are typically numerous opportunities to recover and use heat rejected from refrigeration machinery. The refrigeration heat recovery method is generally suitable when a refrigeration-type compressor is used, and when simultaneous heating and cooling of one or more spaces is required. This method uses one of three different techniques:

- Conventional refrigeration machine method
- Single-bundle condenser, water circuit method
- Double-bundle condenser, water circuit method.

6.6.5.1 Conventional Refrigeration Machine Method

The conventional refrigeration machine method uses a DX cooling coil in conjunction with either a hot water or refrigerant coil. A hot water heating system extracts heat from the refrigerant through a heat exchanger. For direct air heating, a condensing refrigerant coil is used instead of a heat exchanger and water pump. This method is most frequently used for lower capacity systems with reciprocating compressors. An air-cooled condenser is used to reject heat to the ambient outdoor atmosphere when space heating is not required.

6.6.5.2 Single-Bundle Condenser, Water Circuit Method

The single-bundle condenser, water circuit method uses a cooling coil in conjunction with a hot water system for heat recovery. When space heating is not required, heat is rejected through an evaporative cooler, a heat exchanger, and an open cooling tower. Application of this system is limited to a maximum water temperature of 110°F. This system can be used with any compressor type.

6.6.5.3 Double-Bundle Condenser, Water Circuit Method

The double-bundle condenser water circuit method incorporates two separate condenser water circuits—one for the heating system and one for the cooling tower system. Water temperatures up to 125°F can be obtained by using higher compressor speeds, larger impellers, or more than one heat recovery stage. To prevent surging of the compressor under operating load and required condenser water conditions, the condensing temperatures generally must be reduced under part-load conditions. Units shall be selected to operate above 50 percent of full load at all times. Hot water storage tanks may be incorporated into a double-bundle condenser water circuit system.

6.6.6 Condensate Recovery

Condensate recovery from AHUs shall be considered during AHU, chiller, and cooling tower design. Recovering and reusing condensate can create significant water savings over time. Rather than wasting condensate by draining it into a sewer, condensate should be considered a valuable asset that can lead to savings in water, energy, and operating cost. Condensate recovery can apply to air conditioning/refrigeration units or to industrial boiler systems. Because EPA facilities will almost always convert steam energy to hot water for circulation (refer to Section 6.5.1), this section only addresses condensate recovered from HVAC systems (e.g., AHU coils).

Air conditioning and refrigeration units can produce large quantities of condensate, particularly during the summertime and in warm, humid climates. Without recovery systems, condensate water from cooling coils is generally wasted to a sanitary or combined sewer. However, this water is also relatively cool and of sufficient quality for use in a number of other applications, such as cooling towers. Recovery systems can be implemented by installing a pipe to collect water from condensate recovery pans and conveying it via pumps or gravity flow to a cooling tower, reverse osmosis feed water supply for distilled water production, or other applications.

Condensate recovery circuits shall be plumbed and piped separately from any gray water, black water, recovered rain water, and potable water systems and labeled accordingly. Recovered condensate shall be conveyed via gravity flow where possible. Additional flow capacity shall be provided for sprayed-coil systems. All drain pans and piping shall be insulated to eliminate or minimize sweating. If an outfall or connection to the sanitary sewer is provided, a deep-seal (“U”) trap must be installed to forestall any entry of sewer gas into the condensate collection system.

A separate tank or process shall be inserted upstream from any storage/holding tank(s) to accommodate any necessary pre-treatment for bacterial contamination (e.g., chlorination, ozonation, or other sterilization techniques). Depending on system operations, removal of oil and grease from bearings and/or wash-down chemicals from foaming sprays may also be required. This is typically accomplished using skimmers or coalescing separators.

6.6.7 Condensers

Water-cooled condensers shall comply with ASHRAE Standard 15 and the ASME BPVC, Section VIII. Water-cooled condenser shells and tubes shall have removable heads to facilitate tube cleaning. The use of marine water boxes on the condenser shall be considered for ease of tube cleaning (*a marine water box generally has higher first costs but permits access to condenser tubes without the necessity of disconnecting and removing the existing piping*).

All water-cooled condensers must be connected to a re-circulating heat rejecting loop. The heat rejection loop system shall be designed for a minimum 10°F temperature differential and a minimum of 7°F wet bulb approach between the outdoor air temperature and the temperature of the water leaving the heat rejection equipment. Heat tracing shall be provided for piping exposed to weather and for piping installed within 3 ft of the ground surface.

Air-cooled condensers shall meet the standard rating and testing requirements of ARI 460 and ASHRAE Standard 20. Air-cooled condenser intakes shall be located sufficiently distant from any obstructions that would restrict airflow. Air-cooled equipment shall be located away from noise-sensitive areas, and air-cooled condensers shall have refrigerant low-head pressure controls to maintain satisfactory operation during light loading.

6.6.8 Cooling Towers

Induced draft cooling towers with multiple-speed or variable-speed condenser fan controls shall be provided. Cooling tower acceptance and factory rating tests shall be conducted in accordance with Cooling Tower Institute Bulletin ATC-105. The cooling towers shall have a clear distance equal to the height of the tower on the air intake side(s) to keep the air velocity low. Consideration shall be given to piping arrangement and strainer or filter placement such that accumulated solids are easily removed from the system. Clean-outs for sediment removal and flushing from basin and piping shall be provided.

Cooling towers shall be located to avoid problems with water drift (i.e., water vapor loss to the ambient) 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. The cooling tower's foundation, structural elements and connections shall be designed for a 100 miles per hour wind design load. Cooling tower basins and housing shall be constructed of stainless steel. If the cooling tower is located on the building structure, vibration and sound isolation must be provided wherever required. Noise greater than 80 dBa and/or transmission of resonant frequencies is not permissible. Cooling towers should also not be located in proximity to deciduous trees, wherever practicable.

Combustible casings are acceptable in cooling towers, provided that the fill and drift eliminators are non-combustible. (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 ft^3 of combustible fill shall be provided with an automatic sprinkler system, designed in accordance with NFPA 13 and 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.

Cooling towers with airstreams that pass through water shall have the water treated with an EPA-approved biocide to control etiological organisms, where necessary due to local conditions. In addition, processes to remove chlorinated hydrocarbon pesticides, herbicides, or other chemicals using fine filtration, activated carbon, or UV-catalyzed ozonation may be required depending on incoming concentrations. A maintenance program must be established to ensure continued, effective operation of these treatment systems.

Multiple cell towers and isolated basins are required to facilitate O&M and ensure redundancy. The number of cells shall match the number of chillers. Supply piping shall be connected to a manifold to allow for various combinations of on-line equipment. Multiple towers shall have equalization piping between cell basins. The equalization piping shall include isolation valves and automatic shutoff valves between each cell. Cooling towers shall have ladders and platforms for ease of inspections and replacement of packing and other components.

To prevent cavitation, variable speed pumps that serve multiple cooling towers shall not operate below 30 percent of rated capacity. Cooling towers shall be elevated to maintain required net positive suction head on condenser water pumps and to provide a 1.2 m (4 ft) minimum clear space beneath the bottom of the lowest structural member, piping or sump, to allow re-roofing beneath the tower.

6.6.8.1 Cooling Tower Freeze Protection

Special consideration shall be given to de-icing cooling tower fills if they are to operate in sub-freezing weather or serve a chilled water system with a water-side economizer. A manual shutdown for the fan shall be provided. If cooling towers operate intermittently during sub-freezing weather, provisions shall be made for draining all piping during periods of shutdown. For this purpose indoor drain-down basins are preferred to heated wet basins at the cooling tower.

Cooling towers shall also be provided with sump water heating systems if they:

- Will operate year-round, especially during freezing weather
- Are equipped with water-side economizers (i.e., water loops that recover heat from the cooling tower inlet water for useful purposes elsewhere on site).

Condenser water piping located above-grade and down to three feet below grade shall have heat tracing.

6.6.8.2 Controls

Cooling towers shall be provided with BACnet or LONWORKS microprocessor controls, capable of connecting to the BAS. Controls for cooling towers shall conform to NFPA 214 standards. During design of cooling tower fans, use of the following shall be considered to maintain condenser water temperature and reduce overall power consumption:

- Variable-speed drives
- Two-speed motors (if feasible) and on/off controls

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, the 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 that actuate the sump heater as necessary to prevent icing.

6.6.8.3 Discharge to Sanitary Sewer

Continuous bleeding or dumping of water treated with chemicals to sanitary sewer may be prohibited or regulated by local pre-treatment ordinances. Options for recycling bleed and blow-down water on site shall be investigated. If no practicable on-site uses are available, bleed and blow-down shall be minimized, and on-site pretreatment or dilution with other wastewater flows may become necessary.

6.6.8.4 Sub-Metering for Measurement and Verification

Cooling towers shall have flow meters that measure water input (cooling tower make-up water) and output water (blow-down). *Note – Cooling water blow-down is water that has traveled through the cooling tower structure and been cooled by convection and evaporation; it is not identical to boiler blow-down.* Cooling towers shall have a conductivity meter installed to monitor water chemistry and automatically control cooling tower blow-down and water treatment chemical addition. Additional information regarding cooling tower sub-metering is provided in Section 8.5.1 and below in Section 6.9.2.

6.6.8.5 Water Efficiency

The most effective means of optimizing water efficiency (as well as energy efficiency) of a cooling tower is often to optimize the processes or equipment being cooled. This results in a decreased thermal load on the cooling tower and, under most scenarios, less circulation of back-end water to accomplish rejection of this heat energy. Therefore, strategies such as always specifying chillers that meet or exceed FEMP efficiency standards and minimizing heat losses from chilled water circulation piping through effective insulation always must be implemented.

For conventional applications, cooling towers specified shall be designed to operate at a concentration ratio (CR) of 6 or greater (where feasible), in order to limit makeup water addition without simultaneously causing excessive scale buildup on the fill or in ancillary piping. Specific conductivity (an indicator of total dissolved solids [TDS]) meters and volumetric flow meters shall be installed on the makeup and bleed-off water lines, in order to provide real-time indication of TDS and flow rates. A controller (e.g., solenoid switch) shall be connected to the makeup water supply gate valve and be actuated by variations from the conductivity set point (i.e., an increase or decrease in the TDS in the bleed-off line resulting in an out-of-bounds conductivity measurement).

Depending on the application and project requirements, the following design features to enhance water use efficiency of cooling tower(s) shall also be considered:

- Use of VFDs on fan motors. Cooling towers may be good candidates for VFDs because their motors are large, their fans often operate for long periods of time, and the applied heat loads can vary both seasonally and diurnally. High-efficiency motors on fans and efficient transmissions on geared fan drives shall always be specified.

- Hybrid cooling towers, consisting of a "dry" or "air only" section above a "wet" or "water" section. This configuration promotes water efficiency by reducing drift and also aids in limiting visible plumes, which is useful for sites near residential areas or other areas where visibility is vital (e.g., airports, hospital or police helipads). The hybrid configuration also offers operational

Recovery and use of condensate from HVAC systems for on-site irrigation and landscape watering may contribute toward achieving points under the LEED-NC 2009 Water Efficient Landscaping credit. However, for the purpose of this credit, condensate may need to be appropriately treated to remove applicable pollutants of concern to safe, allowable levels.

flexibility (e.g., the wet section alone can be operated during winter plumes when plume rise is less of a concern). Hybrid cooling towers shall be selected based on evaluation of both water efficiency and energy efficiency for the application and operating parameters, because these parameters are sometimes inversely related.

- Side-stream treatment of bleed-off water using filtration or lime softening. Filtration, using sand beds or (for smaller units) paper media, can be beneficial in dusty and dry environments, where removal of hardness can preclude excessive scale formation—in both cases, the cooling tower will likely be able to operate at higher CRs.

- Automated chemical feed systems. For towers with design cooling capacities of greater than 100 ton R that use chemical treatment to control water chemistry, automated chemical feed systems shall be provided unless demonstrated to not be life cycle cost-effective. Automated feed systems shall be calibrated to:

    - Increase or decrease the bleed-off volume based on specific conductivity readings (i.e., instantaneous TDS in the bleed water fraction); and

    - Dose the treatment chemicals based on makeup water flow rates.

  These measures will optimize the instantaneous CR and also reduce labor and analytical testing costs.

- Special consideration shall be given to non-chemical water treatment methods, such as ultrasound, ozonation, electromagnetic pulse-power, filtration, ion exchange, or impressed current, Selection of treatment methods (chemical or non-chemical) shall be dictated by site and project-specific factors, including wastewater discharge pollutant limits and fees, chemical handling and safety requirements, electric power availability and cost, available space and size of units or systems, etc.Coupling with other on-site processes to increase overall facility water efficiency. Bleed-off and/or makeup water may be usable for other non-potable applications, such as flushing toilets or as fire-fighting reserve water. Conversely, other excess water streams (e.g., recovered condensate, reject water from single-pass cooling of refrigeration systems) may be usable as blow-down water for the cooling tower(s).

6.6.9 Process Cooling

EPA facilities will generally have two types of process cooling applications: data centers and research laboratories.

6.6.9.1 Data Centers

A report prepared by Pacific Gas & Electric lists six key principles or design goals for chilled water networks that serve at least one data center at a facility:

- Design for medium temperature chilled water (55°F), in order to eliminate uncontrolled dehumidification and reduce plant operating costs.

- Use aggressive chilled water and condenser water temperature resets to maximize plant efficiency. Specify cooling towers for a 5°F to 7°F approach in order to economically improve chiller performance.

- Design hydronic loops to operate chillers near the design temperature differential, typically achieved by using a variable flow evaporator design and staging controls.

- Use primary-only variable flow pumping systems (i.e., those that circulate chilled water directly through the chiller apparatus). These systems tend to have fewer single points of failure, lower first cost (half the number of pumps), and greater efficiency.

- Consider thermal storage as an alternative to additional mechanical cooling capacity. Thermal storage can significantly reduce electrical demand charges and improve chilled water system reliability.

- Use a high-efficiency, VFD-equipped chiller(s) with appropriate condenser water reset. The VFD will optimize performance as the load on the compressor varies. While data center space load typically does not change over the course of a day or week, the load on the compressor does change as the condenser water supply temperature varies.

Note that increasing the chiller water supply temperature, significant energy gains can be realized. For every 1°F increase in chiller water temperature, chiller efficiency increases by 1 percent to 2 percent; thus, a 10°F temperature rise would be expected to produce efficiency gains of 10 percent to 20 percent.

Air-side economizers may aid in reducing cooling load on central plant system (or packaged, dedicated chillers if used). Data rooms with high cold-aisle temperatures (e.g., 78°F or above) are more likely to benefit from operation of an air-side economizer. Economizers integrated with the AHU(s) and controlled by the BAS are generally the preferred option, because they facilitate better control and require less direct oversight by facility managers. One drawback regarding airside economizers is that they can only be used a few months out of the year in most U.S. climates.

Many layout and demand-side strategies can be utilized to reduce the overall demand data centers exert on the facility cooling plant. In particular, “hot aisle-cold aisle” configurations should be employed, to prevent mixing of exhaust air with fresh (cooler) air supplied by the ventilation system. Aisles must be wide enough for maintenance access and to conform with local fire/safety codes. Shrouds or ducting is sometimes necessary to create the desired airflow circulation patterns.

6.6.9.2 Laboratories

Laboratories often contain numerous critical processes and equipment that require cooling; examples include:

- X-ray equipment

- Freezers for sample storage

- Lasers

- Analytical equipment, such as:

    - Gas chromatography/mass spectrometry (GC/MS)

    - Inductively-coupled plasma/mass spectrometry (ICP/MS)

    - Graphite furnace atomic absorption (GFAA)

    - Electrophoresis.

Laboratories often also require greater stability of temperature and/or pressure in chilled water loops. Maintaining precise temperature set points is critical to operation of sensing lasers in order to ensure repeatable measurements. In addition, analytical equipment depends on temperature stability as follows:

- Cooling of argon plasma torches for the ICP/MS and GFAA methods; and
- Cooling of diffusion pumps associated with GC/MS equipment.

Pressure control/stability is essential where chilled water is circulated through glassware, especially where a positive displacement or turbine chilled water pump is used instead of a centrifugal pump.

Single-pass cooling is not permitted at EPA facilities. Application of small to moderate-sized, dedicated package chillers separate from the centralized space cooling/dehumidification loop is often a feasible and favorable strategy for laboratories. In addition to energy savings (and subsequent operating cost reductions), dedicated chillers often provide more stable control of temperature and/or pressure than central cooling networks. Where separate packaged chillers are infeasible, the hot-gas bypass method of temperature control is preferred to excessive chiller cycling or heater cycling (i.e., reheat of the refrigerant). Where pressure variations are an issue, pressure reducers (internal or external) shall be included in the chiller water loop(s).Where possible, process equipment requiring cooling shall be consolidated in a single space or adjacent spaces, to reduce the number of packaged process chillers required and/or minimize heat transfer and pressure drop losses in dedicated chilled water network(s). Innovative technologies for space cooling (e.g., chilled beams) shall be evaluated, as these allow more of the chiller(s)' capacity to be reserved for process cooling needs (refer to Section 6.3.9). Furthermore, recovery of heat rejected from large process cooling applications (e.g., freezers in central sample storage areas) can often be used to pre-heat room air during the heating season or to generate service hot water.

6.6.10 Avoidance of Ozone Depleting Substances (ODS)

In accordance with the Significant New Alternative Policy (SNAP) rule (59 FR 13044), EPA reviews refrigerant substitutes on the basis of ozone depletion potential, global warming deterrent potential, toxicity, flammability, and exposure potential. Lists of acceptable and unacceptable substitutes are updated several times each year. Refer to the SNAP website for a chronological list of SNAP updates.

Guiding Principle V in the Federal Sustainable Buildings MOU requires that agencies, where possible, eliminate the use of ODS' during and after construction where alternative environmentally preferable products are available, consistent with either the Montreal Protocol and Title VI of the CAAA. Because substitutes for CFCs (i.e., HCFCs) are commercially available, new construction and major renovation projects shall not utilize CFCs in chillers or other mechanical equipment. In addition, where feasible, the project designers should consider the use of absorption chillers or other units that have negligible effects on stratospheric ozone HCFCs, while currently allowed and acceptable, have a low (less than 0.2) ozone depletion potential.

6.6.11 Economizers

6.6.11.1 Air-Side Economizers ("Economizer Cycle")

During cool weather, the outside ambient temperature can help save energy in chilled water systems. The low temperature of the cooling tower water supply enables "free" or less-costly cooling of research laboratories, computer rooms, and office buildings. This "free" cooling can be realized if the central chiller plant incorporates a plate-and-frame heat exchanger to generate chilled water while the chiller's compressor is shut down.

“Free” cooling can be used to save energy whenever the outside wet-bulb temperature drops below the required chilled water set point. The cost feasibility of the economizer cycle tends to be greater for facilities that have interior zones requiring year-round cooling and facilities with internal heat gains that exceed heat losses through the building envelope (e.g., relatively modern facilities with high plug loads).

Air-side economizers shall provide leaving air conditions no greater than 50°F dew point temperature or 70 percent relative humidity. The air-side economizer cycle should not be used in humid climates and for spaces where humidity control is critical, such as in computer rooms. Outdoor air dampers should be located away from the intake louver and after the duct transition to minimize exposure to weather and reduce the size/cost of required dampers. Air change-over shall be triggered by the outdoor air dry bulb temperature, rather than by enthalpy changes or changes in the outdoor/return air ratio.

6.6.11.2 Water-Side Economizers

In certain climate conditions, cooling towers are capable of producing condenser water cold enough to cool the building space or processes without chiller operation. Water-side economizer cycles are particularly cost-effective in the low humidity climates of the western U.S. (where they can also be paired with evaporative coolers in lieu of large cooling towers). Water-side economizer systems shall be used only in areas where, or at times when, the outdoor air wet bulb temperature is below 40°F. Water-side economizers shall utilize a plate-and-frame heat exchanger piped in a parallel arrangement with its respective chiller (i.e., backup chiller).

6.6.12 Evaporative Cooling

An evaporative cooling system is one that removes latent heat from the ambient air through the evaporation of water. These systems are most commonly used in dry climates, such as the desert southwest U.S., where relative humidity is usually very low (and thus the air has high available moisture-holding capacity). Generally, evaporative cooling shall be considered for climates and seasons where the dry bulb temperature exceeds 85°F and the concurrent wet bulb temperature is below 70°F.

Two types of systems are discussed herein: direct and indirect. Direct systems involve mixing of the water to be evaporated with the air. Indirect systems evaporate water inside a coil, duct, or heat exchanger shell, and heat is transferred across a boundary (e.g., coil wall) that separates the air from the water being evaporated.

Water usage will naturally increase for whichever type of evaporative cooler is installed. Water conservation requirements and the life-cycle cost of obtaining water must be factored into the evaluation/selection process.

Single-stage evaporative coolers are not recommended for areas where the temperature frequently exceeds 100°F. Therefore, because these temperatures are common in the desert southwest U.S., this section discusses only two-stage (compound) evaporative coolers. These operate as follows:

- The first stage of cooling is an indirect-section evaporative cooler, which lowers both the dry bulb and wet bulb temperatures of the incoming supply air. This is a constant humidity ratio process. The supply air is then conveyed through a direct-section evaporative cooler for further cooling down to the required supply temperature and relative humidity

- The second stage is a constant wet bulb temperature process. An automatic reservoir purges and drains completely during off cycles to prevent biological growth inside the water tubes.

Compound evaporative coolers shall have minimum heat removal efficiencies of 60 percent for the indirect stage and 90 percent for the direct stage, where efficiency is defined as follows:

Efficiency = $(T_1 – T_2) / (T_1 – T_w) \times 100$, where

T_1 = entering dry bulb temperature

T_2 = leaving dry bulb temperature

T_w = entering wet bulb temperature.

6.6.12.1 Indirect Cooling Stage

The indirect stage equipment shall include the following components:

- Heat exchanger (shell-and-tube, plate-and-frame, or coils)
- Evaporative media
- Re-circulating pump with suction strainer
- Sump drain
- Overflow pan
- Automatic fill and level control
- Secondary air exhaust fan
- Distribution header and internal piping.

UVC emitters shall be incorporated downstream of the heat exchanger(s) and above drain pans, to control airborne and surface microbial growth and transfer. Power output and intensity shall be as recommended by the manufacturer.

Evaporative media shall consist of self-cleaning, refined cellulose fibers impregnated with insoluble anti-rot salts and rigidifying saturants. The media shall be capable of withstanding a maximum air face velocity of 700 fpm without moisture carryover.

The secondary air exhaust fan shall be an appropriately sized and specified axial (propeller-type) or centrifugal fan (refer to Section 6.3.3). The fan shall either operate on the fan curve; have a sheaved, V-belt drive to allow speed adjustment; or shall have a VFD. If used, centrifugal fans shall have forward-curved blades, unless backward-curved blades are approved by EPA due to high system capacity and energy consumption.

6.6.12.2 Direct Cooling Stage

Unless otherwise specified, the direct cooling section shall be one of the following:

- Drip-type with stationary wetted pad

- Rotary-type with revolving drum or disk
- Washer (eliminator type).

The evaporative media shall consist of refined cellulose fibers impregnated with copper 8-quinolinolate. Water reservoirs shall be sized with a minimum of five gallons of fluid capacity per 1,000 cfm passing through the cooler section. Automatic flush (electric dump) valves and timers shall be provided, and shall consist of a cast bronze valve with neoprene-diaphragm solenoid and timer. Fan plenums shall be insulated on the interior (including duct liner covers), and fresh air intake hoods shall be equipped with bird screens. Vibration isolators may be required in some applications.

6.7 Service Hot Water

Domestic hot water supplies shall be generated and stored at a minimum of 140°F, and tempered to deliver 124°F water to outlets or in accordance with state code. Hand washing, lavatory, sink, and similar fixtures accessible to the disabled, elderly, or children shall be tempered to deliver 85°F to 109°F water temperatures at the fixture or group of battery fixtures. Bathing and showering fixtures (except emergency showering) shall be tempered to deliver 85°F to 120°F water temperatures at the fixture or group of battery fixtures.

Individual fixture or battery thermostatic mixing valves shall be provided where distributed outlet temperatures may exceed 124°F. Hot water supply to dishwashers shall be at 140°F, and the temperature shall be boosted from 140ºF to 180°F for the final sanitizing rinse. Heat pump-powered hot water heaters shall be used where energy cost savings will result.

6.7.1 Hot Water Heating Units

Domestic potable hot water shall be generated by water heaters utilizing natural gas, electricity, or steam as the energy source. Selection shall be supported by an economic evaluation incorporating first cost, operating costs, and life-cycle costs. Cold (or pre-heated) water supply to water heaters shall include, at a minimum the following components:

- Service valve
- Check valve
- Expansion tank (sized for expansion of storage capacity only)
- 27-inch heat trap
- Mixing valve bypass primer
- Hot water return connection.

The 27-inch trap height (minimum) shall be provided at water heater cold water inlets for energy savings.

Cold water temperatures supplied from the utility source vary in temperature by season and regional location. The mechanical designer shall obtain seasonal cold water service temperatures supplied by the water utility (a minimum of the past three years' worth is preferred). The lowest seasonal cold water service temperatures from the past three years shall be utilized in calculation and application of:

- Domestic hot water load (and corresponding heating load/energy requirements)
- Heating energy source (steam, heating hot water, gas)
- Makeup cold water to the water heating energy source.

Preheating the cold water supply to the domestic water heater, utilizing steam condensate (where available) or hot water returned to the boilers, shall be considered.

Instantaneous water heaters are not permitted as a primary source. For incidental use, sporadic equipment demands, or remote individual fixtures (i.e. lavatory, sink, shower, service sink), the use of instantaneous water heaters is permitted. Point-of-use instantaneous water heaters are permitted for use at emergency fixtures to supply “tepid water” immediately at the emergency fixture or group of emergency fixtures.

6.7.2 Distribution Piping

The distribution system shall consist of a piping system that connects water heater(s) to all fixtures, equipment, and outlet demands requiring potable domestic hot water. Circulation return systems with circuit setters/balancing valves or temperature maintenance systems shall be provided for all branches in excess of 25 feet from the water heater or circulated distribution main. Domestic hot water, at the temperatures specified herein, shall be available at each hot water outlet within 15 seconds of the time of operation.

Domestic hot water return circuits of substantially varying pressures as a result of pressure zoning or static head cannot successfully be joined to a single pressure zone water heater. Individual pressure zone water heater(s) shall be located within the pressure zone(s), where return pressures would vary substantially causing dead head on the lower pressure return circuits. Hot water return systems shall have circuit setters (balancing valves) and test plugs at each return circuit, and systems shall be balanced.

There shall be no dead legs or capped spurs within the potable domestic water plumbing system, without return circulation. Rubber fittings and device components shall not be permitted within the potable domestic hot water or return systems, as they have been associated with persistent colonization of *Legionella spp*. For additional information on water temperature, control of *Legionella spp*., and water safety, refer to the U.S. (CDC) publication, *Guidelines for Environmental Infection Control in Healthcare Facilities* (Section 5, “Maintenance Procedures Used to Decrease Survival and Multiplication of *Legionella spp*. in Potable-Water Distribution Systems”) and ANSI Standard Z358.1*)*.

Emergency fixtures—eyewash (0.4 gpm per fountain), face wash (3 gpm each), or shower (20 gpm each)—shall be tempered immediately at the fixture or group of fixtures (within 25 feet) to deliver “tepid water” 85°F to 100°F, at 30 psig, within 10 seconds, for a minimum period of 15 minutes. The design shall account for energy loss due to temperature drop across the valve (generally 20°F) during flow.

6.7.3 Pumps

Pumps for service hot water shall conform with the specifications contained in Section 6.5.

6.7.4 Solar Domestic Hot Water Heating

Solar energy systems used for domestic hot water heating shall conform with the specifications contained in Section 6.5.7 (*note*

EPA facilities can earn points toward LEED-NC 2009 certification for using certain on-site renewable energy systems to offset building energy costs. Solar heating systems that transfer thermal energy using collection panels; pumps and/or fans; and hot water storage tanks are eligible for this credit.

that solar systems used for space heating and domestic hot water heating are fundamentally equivalent; only the sizing and design parameters may differ). The system shall be capable of supplying a minimum of five gallons per person per day (more if hot water is required for process loads). Temperature-actuated tempering valves shall be installed to ensure that scalding hot water is not delivered to individual fixtures, in accordance with Section 6.9.1 below.

6.7.5 Drain Line Heat Recovery

The energy required to heat domestic or process hot water may be reduced by pre-heating the inlet water using waste heat from drain lines. Kitchens and laundries offer the greatest opportunities for this type of heat recovery, because the wastewater temperatures are fairly high and operating schedules are predictable. The simplest such system has a coil of copper pipe wrapped tightly around a section of copper drain line. Cold water flowing to the water heater flows through this coil and is pre-heated by hot water moving through the drain line. If being used to pre-heat a potable water stream, the waste hot water and inlet water flows must be adequately isolated from each other, and the system must be periodically checked for leaks (e.g., using a soap solution) to confirm isolation is maintained.

6.8 Other Systems

6.8.1 Refrigeration/Cold Storage

Residential/light commercial-size refrigerators (i.e., those used for storing food and drinks) shall comply with the applicable ENERGY STAR standard. Laboratory refrigerators, freezers, and walk-in coolers shall comply with ARI 420 or ARI 520, as applicable. All refrigerators shall comply with ASME 15*.*

Condensing units shall be fully- or semi-hermetic type, depending on the application and local environment. Refrigerant shall be R-404A unless otherwise specified. Condensing units and evaporators shall be factory-assembled and UL-listed. Evaporators shall be forced-air type. Air discharge shall be parallel to the walk-in ceiling.

Freezer evaporators shall have an automatic electric defrost system, including heater, time clock, fan delay control, and heated drain pan. The defrost shall be time-initiated and temperature-terminated, with built-in fail-safe control. All systems shall include a pump-down cycle to provide additional protection against refrigerant surge.

6.8.1.1 Walk-in Environmental and Cold Storage Rooms

Walk-in environmental rooms are rooms in which temperature and/or relative humidity is controlled at a single set condition within specific tolerances, regardless of activity in the room. Walk-in environmental rooms shall be capable of maintaining a 4 degrees Celsius (°C) (39.2°F) with a uniformity of 0.5°C (0.9°F) and a maximum gradient of 1°C (1.8°F), unless otherwise specified. A walk-in cold storage room shall be capable of maintaining a -20°C (-4°F) room temperature, with a uniformity of 2°C (-3.6°F) and a maximum gradient of 3°C (-5.4°F), unless otherwise specified.

Walk-in environmental and cold storage rooms shall feature temperature displays visible from a contiguous corridor, and shall be capable of producing a continuous reading of temperature (and transmitting these data to the BAS). Alarm systems with manual override capability shall be provided to advise room operators of fault conditions. Ventilation shall be provided if work is performed inside these rooms. Doors 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 rooms shall include shelving. Walk-in coolers are considered enclosed spaces and require automatic fire sprinkler protection inside them. Refer to Chapter 9 of this Manual for additional information. Walk-in cold storage rooms shall have oxygen sensors and alarms to ensure that oxygen is not being displaced.

A separate refrigeration system shall be provided for walk-in cold storage and environmental rooms. If refrigeration is provided by the building's primary chiller water system, a backup, self-contained system must be provided.

Where necessary, cold storage rooms shall have systems to prevent formation and buildup of ice on walking surfaces.

6.8.2 Laboratory Gas Storage and Distribution Systems

Systems for flammable and non-flammable gas storage and distribution must meet the following requirements:

6.8.2.1 General Requirements

Special gas services for flammable and non-flammable gases shall be provided to all laboratories requiring their use. Gases shall be stored and piped in accordance with the following standards:

- NFPA 45
- NFPA 50A
- NFPA 50B
- NFPA 54
- NFPA 55.

In situations not covered by NFPA code, the Compressed Gas Association shall be consulted for guidance. No piping from any of these systems shall be run above or in the exit access corridors.

Gas cylinders for non-flammable gases, both in-use and standby, shall be manifolded and distributed from an area that is:

- Located as far as possible from frequently used and occupied areas of the building
- Accessible from either the central storage area or directly from the loading and receiving dock area.

This space shall be designed and ventilated in accordance with applicable code requirements.

Flammable gas cylinders shall be exposed at the point of use only and shall otherwise be housed in approved cabinet enclosures that are mechanically ventilated to atmosphere and equipped with leak detection monitoring devices and visible/audible alarms.

Before acceptance, all gas distribution systems must be pressure-tested for tightness 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.

6.8.2.2 Distribution Systems

For all laboratories except metals analysis laboratories, a seamless copper piping gas distribution system for non-flammable gases shall be provided to all designated laboratory workspaces. 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. Regulator valves, pipe sleeves, and other auxiliary equipment required to furnish gas at the required pressures shall be provided.

Pipe sizes shall be selected to ensure that the pressure delivered at the point of use (i.e., after line and fitting losses) is adequate for the application. The number and type of gas outlets in each room will be indicated on the room data sheets. Exact and final outlet locations in each laboratory must be approved by EPA during the design phase. The system design shall include a capability for individual room cut-off.

6.8.2.3 Distribution Systems for Metals Laboratories

For all laboratories used for metals analysis, a double-walled piping system, consisting of seamless Teflon®-piping inside a larger-diameter PVC containment pipe, shall be installed. For the inner pipe, alternatives to Teflon® construction may be utilized if approved by EPA. Pipe sizes shall be selected to ensure that the pressure delivered at the point of use (i.e., after line and fitting losses) is adequate for the application.

6.8.2.4 Bottle Gas Supply

The bottle gas supply shall be provided with duty and standby sets with automatic change-over valves and controls. For all gases, an indicator panel shall be installed close to the point of use in each of the laboratories (the distance between the point of use and the panel shall not exceed 75 feet).

When toxic or explosive gases and/or simple asphyxiants are used in a confined space, a multi-point 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 linked with the BAS. The number and type of sensors and 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 and shall have an audible and a visible alarm. The control panel shall also have a factory-wired terminal strip to interface with the BAS for remote monitoring and alarms.

6.8.2.5 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 inert 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.

The project mechanical or safety engineer shall determine whether an oxygen meter should be installed in confined areas or small areas where liquid nitrogen and/or argon are stored, distributed, or transferred. An example of a calculation tool can be found at http://www.oxigraf.com/technical_support.html. The project mechanical or safety engineer shall assume that 100 percent of the liquid nitrogen or liquid argon is released into the space.

6.8.2.6 Natural Gas Distribution System

Unless otherwise specified in the project criteria, each laboratory facility must have a natural gas distribution system. Refer to Section 6.10.6 for natural gas distribution system requirements.

6.8.2.7 Compressed Air Systems

Where compressed air systems are required, these systems should be provided with oil and water traps, a dryer, and all necessary controls and appurtenances. Unless otherwise specified in the project criteria, each compressed air system shall have duplex compressors (i.e., one redundant compressor), with an automatic lead/lag switch and a single compressed air tank. Compressed air systems for processes shall be completely independent of any existing pneumatic systems for HVAC controls .

The compressed air system shall include a water trap and pressure regulator(s) at each laboratory room or area. An audible alarm and remote annunciation shall be provided to alert personnel to a loss of air pressure. Air compressors shall be equipped with vibration pads and springs, as required, to diminish vibration and sound generated by compressors. In addition, compressor locations should be selected so as to minimize transmission of vibration and sound to the building or rooms that the compressors service.

6.8.2.8 Vacuum Systems

Where a laboratory vacuum system is required, it shall consist of several vacuum pumps capable of evacuating air at a regulated suction of 25 inches of mercury or as specified in the project criteria. 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 annunciator shall be provided to alert personnel to a loss of vacuum.

Vacuum pumps shall be equipped with vibration pads and springs, as required, to substantially reduce vibration and sound generated by the pumps. Furthermore, the pump location should be selected so as to minimize transmission of vibration and sound to the building or rooms that the pumps services.

6.8.3 Renewable Energy Generation Technologies

6.8.3.1 Biomass-Fired Boilers

This section discusses boilers that combust solid biomass residues for the production of hot water, steam, and/or electricity primarily for on-site use. Biomass can also be gasified and used in that form as an energy source. Biomass is defined in EISA 2007 [Title II, Subtitle A, Section 201(l)] as follows:

- Planted crops and crop residue harvested from agricultural land cleared or cultivated at any time prior to the enactment of the Statute and that is either actively managed or fallow, and non-forested
- Planted trees and tree residue from actively managed tree plantations on non-Federal land cleared at any time prior to enactment of the Statute, including land belonging to an Indian tribe or an Indian individual, that is held in trust by the U.S. or subject to a restriction against alienation imposed by the U.S.
- Animal waste material and animal byproducts

- Slash and pre-commercial thinnings that are from non-Federal forestlands, including forestlands belonging to an Indian tribe or an Indian individual, that are held in trust by the U.S. or subject to a restriction against alienation imposed by the U.S., but not forests or forestlands that are ecological communities with a global or state ranking of “critically imperiled,” “imperiled,” or “rare” pursuant to a state natural heritage program, old growth forest, or late successional forest
- Biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, at risk from wildfire
- Algae; or
- Separated yard waste or food waste, including recycled cooking and trap grease.

Biomass combustion systems are typically below 50 megawatts, electric (MW_e) in size (or less than 500 MBTU per hour heat rate). The two most-commonly used types of boilers for biomass firing are stoker boilers and fluidized bed boilers. Either of these can be fueled entirely with biomass fuel or co-fired with a combination of biomass and coal. Stoker boilers are designed to feed fuel onto a series of grates where it is burned partially on the grates and partially in suspension (the smaller, lighter particles). The stoker is located within the furnace section of the boiler and is designed to remove the ash residue after combustion. Heat is transferred from the fire and combustion gases to water tubes within the boiler walls.

In fluidized bed boilers, the fuel is burned in a bed of hot inert or incombustible particles suspended by an upward flow of combustion air that is injected from beneath. The “scrubbing” action of the bed material on the fuel enhances the combustion process by stripping away the CO_2 and solids residue (char) that normally forms around the fuel particles. Often, limestone is injected to chemically remove sulfur by converting it to calcium sulfate (gypsum). In addition, the fluidized bed process allows oxygen to reach the combustible material most readily and thus increases the rate and efficiency of the combustion process. The effective mixing of the bed makes fluidized bed boilers well-suited to burn solid refuse, wood waste, waste coals, and other less-conventional fuels.

EPA facilities that employ certain biomass and biogas combustion/energy production systems may be eligible for points under the On-Site Renewable Energy Use credit for LEED-NC 2009 certification. The LEED Reference Guide defines the eligible types of biomass combustion.

Biomass energy systems should be considered for facilities that benefit from on-site electricity generation, especially when the waste heat from that power generation can be used for industrial processes or district heating (combined heat and power). Biomass energy is most feasible when there is an on-site (or nearby) source of fuel, such as waste wood from furniture manufacturing or agricultural crop residues.

Biomass boilers shall meet or exceed the efficiency requirements indicated in Table 6-14:

Table 6-14: Biomass Boiler Efficiency as a Function of Input Fuel and Combustion Characteristics

Characteristics	Biomass Stoker		Biomass Fluidized Bed	
	Dry	As Received	Dry	As Received
Excess air (%)	50	50	50	50
Dry flue gas (lb/lb fuel)	15.25	10.675	15.25	10.675
Final exhaust temperature (°F)	350	350	350	350
HHV of the fuel (BTU/lb)	8,500	5,950	8,500	5,950
Moisture content of the fuel (%)	0	30	0	30
Hydrogen percent in the fuel (%)	4.59	3.21	4.59	3.21
Efficiency Losses				
Dry flue gas losses (%)	11.63	11.63	11.63	11.63
Moisture in fuel (%)	0	5.90	0	5.90
Latent heat (%)	5.69	5.69	5.69	5.69
Unburned fuel (%)[1]	3.50	3.50	0.25	0.25
Radiation and miscellaneous (%)[2]	2.03	2.03	2.03	2.03
Total Combustion Losses	**22.85**	**28.75**	**19.60**	**25.50**
Boiler Efficiency HHV Basis (%)	**77.15**	**71.25**	**80.40**	**74.50**

Source: U.S. EPA, Combined Heat and Power Partnership, *Biomass Combined Heat and Power Catalog of Technologies*, September 2007, Chapter 5, p. 36, http://www.epa.gov/chp/documents/biomass_chp_catalog_part5.pdf.

1. Estimated value.

2. Includes radiation, moisture in the air, and other miscellaneous losses.

BTU – British Thermal Unit; lb – pounds; HHV – higher heating value

Biomass boiler units shall be capable of fulfilling all applicable state and Federal permitting requirements for a construction/operating (synthetic minor) source or a Title V source, as applicable. The minimum air pollution control equipment train shall include a cyclone separator for larger particulate matter (PM). In many cases, a filter baghouse or ESP to remove finer PM and/or nitrogen oxides control (e.g., selective catalytic or non-catalytic reduction) will be required to comply with local air pollution control standards.

The boiler(s) shall be designed to minimize the quantity of ash produced and requiring subsequent disposal. The boiler shall be designed to operate with a minimal number of personnel, through extensive use of automation for process equipment and controls. Water sprays or other equipment to control fugitive particulate emissions from storage piles shall be provided, as needed. A shredder and magnetic separator shall be provided to ensure near-uniform sizing of wood waste or biomass (to maximize combustion efficiency) and to prevent ferrous metals (e.g., nails, screws) from becoming entrained in the ash, respectively.

Exhaust from biomass boilers and storage areas shall be located at least 50 feet from building makeup air inlets (or as prescribed by local codes and regulations).

6.8.3.2 Waste Heat from Electrical Power Generation

Waste heat from electrical power generation can also be used for water heating. With fuel cells and micro-turbines beginning to be used for distributed power generation in buildings, for example, there are opportunities to recover the waste heat. Refer to Section 7.8 of this Manual for additional information on these electricity generating options.

6.8.4 Elevators and Escalators

6.8.4.1 General Requirements

Elevators, dumbwaiters, escalators, and moving walks shall be specified and installed in accordance with ANSI Standard A17.1,GSA PBS-P100, and the IBC. Conveyor system lubricants must be free of polychlorinated biphenyls (PCBs). In addition, the use of U.S. Department of Agriculture (USDA)-identified biobased lubricants shall be evaluated, and such lubricants shall meet the minimum bio-based content prescribed in 7 CFR 2902 (for lubricants, the target is 68 percent minimum). Other requirements and specification are described below.

6.8.4.2 Elevator Recall

In accordance with ANSI A17.1, all automatic elevators having a travel distance of 80 inches or more, that penetrate a floor, or are required to be enclosed in a fire-resistive hoistway shall be recalled when any fire alarm-initiating device, such as elevator lobby smoke detectors, manual fire alarm stations, or sprinkler system water-flow switches, is activated. Recall is not required when travel is less than 80 inches or if recall is not required by the local jurisdiction. 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. Elevators meeting the above criteria must also be provided with Phase II Firefighters' Emergency Operation capabilities.

6.8.4.3 Elevator 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.

6.8.4.4 Elevator Capture Floor

An alternate capture floor shall be provided, in accordance with NFPA 101 and ANSI/ASME A17.1. Activation of an alarm-initiating device on the main capture floor shall return the elevators to the alternate capture floor.

6.8.4.5 Elevator Signage

Signs as required by ANSI A17.1 must be placed in the elevator lobbies next to all elevators to inform occupants not to use the elevators if there is a fire. Signage inside the elevator car (e.g. Firefighter Service Operation) shall also comply with ANSI A17.1.

6.8.4.6 Transport of Chemicals in Elevators

If elevators are used to transport chemicals, provisions shall be made to ensure that non-laboratory personnel and spaces (administrative or business occupancies) are not exposed to or contaminated by chemical substances. In general, only specially-designated freight elevators shall be used to transport chemicals. Chemicals must be packaged in accordance with U.S. Department of Transportation 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 may be used to achieve this goal.

6.8.4.7 Elevator Machine Rooms

A dedicated heating and/or cooling system must be provided to maintain room conditions in Table 6-1 and as required by the equipment specifications. If the building is not equipped throughout with sprinklers, hoist-way venting will be required.

6.8.4.8 Venting

Venting of hoistways shall meet the requirements presented in the IBC.

6.8.4.9 Sprinklers

In accordance with GSA PBS-P100, each elevator machine room shall be provided with a wet-pipe sprinkler system using standard response sprinklers. The sprinkler system for the elevator machine room shall be provided with separate manual isolation valves and a separate water flow switch located outside the room in an accessible location. Tamper switches shall be provided on all such valves. Sprinkler protected elevator machine rooms containing elevator control equipment shall be provided with a means to disconnect automatically the main line power supply to the affected elevator prior to the application of water in accordance with the requirements in NFPA 72. Enclosed elevator lobbies are not required to be installed in buildings protected throughout by an automatic sprinkler system.

6.8.4.10 Entrapment Prevention

When the fire protection engineer has determined that there may be a possibility that occupants may get trapped in an elevator cab due to the power shut-down of the elevator controller prior to complete elevator recall via Phase I Emergency Recall Operation, earthquake mode emergency condition software shall be incorporated into the project. This software shall be interfaced with heat detectors installed in the elevator machine room as required by PBS-P100, Section 7.15. Activation of this system will cause the elevator to proceed to the nearest landing, park, open the doors and shut down. Heat detectors installed shall have both a lower temperature rating and higher sensitivity rating than the automatic sprinklers installed in the elevator machine room.

6.8.4.11 Escalators

Floor openings provided for escalators shall be protected in accordance with the IBC.

6.8.5 Atrium Smoke Removal Systems

Atrium smoke removal systems shall be designed and installed in accordance with the requirements in the IBC.

6.9 Measurement, Monitoring, and Recording Equipment

All utilities including electric, gas, oil, and potable water utilities to be monitored shall be metered and tracked by the BAS on a building-wide level. All meters shall be compatible with the installed control system, shall be provided with signaling devices, and shall seamlessly interface with the BAS. Sub-metering of electricity, thermal energy, and water usage should be installed where practicable. Additional information regarding the BAS and utility sub-metering in contained in Chapter 8 of this Manual.

6.9.1 Advanced Metering

Advanced meters are defined as metering systems that measure and record interval data at least hourly and transmit measurements over a communication network to a remote central collection point at least daily. Advanced metering for electricity is required for all Federal buildings by October 1, 2012, and similar advanced metering is required for natural gas and district-supplied steam by October 1, 2016. It is EPA's present policy to install advanced metering at all of its facilities, except where specifically exempted by the EPA project manager.

EPA facilities can earn points toward LEED-NC 2009 certification for developing and implementing a measurement and verification strategy to track the facility's energy consumption. There are two possible options for achieving this credit, which are detailed in the LEED Reference Guide (both options require that the facility conduct corrective actions if energy savings targets are not achieved).

6.9.2 Flow Meters for Liquids

Water flow and/or energy measuring devices are required for each chiller, hot water boiler, pump, and connection to district energy plants. Individual water flow or energy measuring devices shall also be provided for chilled water lines serving computer rooms and chilled water and hot water lines to leased spaces. All flow-measuring devices shall be capable of communicating with the BAS.

Liquid flow meters shall be magnetic, turbine type, ultrasonic, or other type approved by EPA. Flow meter accuracy shall be within ± 2 percent. The pressure drop across the flow meter shall not exceed 5 psig under maximum flow conditions. Wherever possible, a straight, unobstructed length of at least 10 pipe diameters shall be provided upstream of the flow meter and a similar straight, unobstructed run of at least five pipe diameters shall be provided downstream of the flow meter.

6.9.3 Flow Meters for Air in Ducts

Wilson Grids (or similar airflow measuring grids) are required for all central AHUs. Measuring grids shall be provided at the supply air duct, return air duct, and the outside air duct. Airflow measuring grids must be sized to give accurate readings at minimum flow. In some instances, it may be necessary to reduce the duct size at individual measuring stations to enable accurate measurement. Each grid shall be equipped with a pressure transducer linked with the BAS (liquid-filled and/or electronic manometers to provide on-site readouts are optional).

Refer to Section 6.3 for air duct requirements to guide the selection and placement of flow meters for air in ducts.

6.9.4 Temperature and Pressure Sensors

Each piece of mechanical equipment shall be provided with the instrumentation or test ports to measure and verify temperatures and pressures. These shall consist of permanently installed, calibrated sensors, such as pressure gages, pitot tubes, manometers, thermometers, and/or thermocouples to accurately measure and pressures and temperatures. Thermometers and pressure gauges are required on the suction and discharge of all pumps, chillers, boilers, heat exchangers, cooling coils, heating coils, and cooling towers.

Pressure and temperature sensors shall comply with the requirements contained in Chapter 8, Table 8-1. Local chart recorders shall be installed where specified by EPA.

To avoid pressure gauge tolerance errors, a single pressure gauge may be installed and valved to sense both supply and return conditions. For coils with less than 10 gpm of flow, provisions for use of portable instruments to check temperatures and pressures shall be made. Duct static pressure gauges shall be provided for the central AHU air supply fan discharge, branch take-offs of vertical supply risers, and at all duct locations at which static pressure readings are being monitored to control the operation of a VAV system. Differential static pressure gauges shall be placed across filters in AHUs. A temperature gauge is required at the outside air intake to each AHU.

Refer to Table 8-3 in Chapter 8 of this Manual for a listing of measuring points and associated parameters for the HVAC system.

6.9.5 Water Meters

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 shall be equipped with flow-totalizing sub-meters. Meters and sub-meters shall be installed and calibrated in accordance with the manufacturer's specifications.

Dedicated, centralized laboratory water supply systems, such as de-ionized water, reverse osmosis water, or culture water systems shall be equipped with flow totalizing meters that measure total water consumption. This sub-metering data should be automatically fed to the BAS for archiving and report generation.

6.9.6 Air Stack Monitoring

Air stack monitors shall be installed where applicable to measure releases of air pollutants consistent with a permitted state synthetic minor source or Title V major source. Additional detailed information on stack monitoring will be contained in a facility's air emissions permit issued by the state or local environmental agency having jurisdiction.

6.9.7 Other Air Monitoring

Vehicle garage exhaust fans shall generally be activated based upon CO sensors within garages and parking areas. CO sensors shall also be located in all floor areas where vertical shafts penetrate the garage areas and in any spaces with fuel-burning equipment. The activation level shall be 9 ppm of CO, except where approved by EPA. Refer to Section 6.3.8 for information on CO_2 monitoring and DCV.

Oxygen (O_2) deficiency sensors shall be installed in all areas with high density storage of cryogenic materials in tanks and/or Dewar flasks (dewars), especially in indoor air in areas where filled or partially filled dewars are stored. The sensor(s) shall be a lambda-type, electrochemical cell detector with a minimum sensitivity of 0.1 percent O_2. The sensor(s) shall be equipped with a "Low" alarm that activates at 19.5 percent O_2 (or other threshold defined by the EPA SHEMD. Both audible and visual warning devices shall be provided and linked to the sensor(s).

6.10 Plumbing and Piping

EO 13514 requires EPA to reduce water consumption intensity, relative to the baseline of the agency's water consumption in FY 2007, through life-cycle cost effective measures by 2 percent annually or a total of 26 percent by the end of FY 2020. In addition, per EO 13423 (the requirements of which were codified in the Omnibus Appropriations Act of 2009), total facility indoor water consumption must be reduced by at least 20 percent below the relevant facility's baseline. This reduction must be achieved *after* meeting the fixture performance requirements contained in EPAct 1992, the 2006 Uniform Plumbing Code, and the 2006 International Plumbing Code.

6.10.1 Water Supply Systems

6.10.1.1 General Requirements

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 UPC or local plumbing code and the ASHRAE Handbook. Access panels shall be provided where maintenance or replacement of equipment, valves, or other devices is necessary. Pipes shall be marked in accordance with ASME AB.1 and shall conform with requirements of Chapter 5 of GSA P100 and NFPA 45, Chapter 8.2, as applicable.

6.10.1.2 Potable Water Supply Network

Type K copper tubing shall be used for below-grade supply piping. Type L copper tubing shall be used for above-grade supply piping. The laboratory potable-water supply shall be piped in Type K or Type L copper. PB plastic pipe and/or tubing may be used in lieu of copper tubing above grade, where it would not be subject to impact damage or not be otherwise incompatible with 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.

EPA facilities can earn one point toward LEED-NC 2009 certification for using low VOC-emitting adhesives and sealants (e.g., plumbers putty, ABS welding flux). The allowable VOC emissions thresholds for each material are contained in the LEED Reference Guide.

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 Schedule 80 threaded connections. No lead solder shall be used for copper pipe in potable-water systems. Dielectric connections shall be made between ferrous and non-ferrous metallic pipe.

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. Manufactured water hammer arresters shall be provided, and shall be installed in appropriate locations.

Provision for expansion shall be made where thermal expansion and contraction may cause piping systems to move. This movement shall be accommodated by using:

- The inherent flexibility of the piping system as designed
- Loops
- Manufactured expansion joints; and/or
- Couplings.

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 UPC and NFPA 13, respectively.

6.10.1.3 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, indicating that the product complies with the health effects requirements of NSF/ANSI Standard 61 for materials designed for contact with potable water, 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 816-B-94-002, *3Ts for Reducing Lead in Drinking Water in Schools—Revised Technical Guidance,* October 2006.. Testing of the building's potable water system and the potable water supply main shall be coordinated with the local water company, county health department, and the state environmental protection agency, as applicable.

6.10.1.4 Sterilization

New water supply systems or existing supply systems that have undergone rehabilitation will require sterilization in accordance with American Water Works Association (AWWA) C651, AWWA C652, applicable provisions of the Uniform Plumbing Code, and/or applicable state and local plumbing codes.

6.10.1.5 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). Hub-less, cast iron, soil pipe may be used in locations where piping is accessible. Above-grade lines that are 12 inches in diameter and larger shall be either hub-less or hub-type (with gasket), service weight, cast iron pipe. Lines less than 12 inches in diameter may be ABS pipe where allowed by the project criteria. Pipe and fittings shall be joined by solvent cement or elastomeric seals. Cast iron soil pipe fittings and connections shall comply with Cast Iron Soil Pipe Institute guidelines. Provisions for expansion shall be included, as above.

Underground lines servicing laboratory areas shall be acid-resistant sewer pipe, conforming with one of the following, as applicable:

- ASTM D2447
- ASTM D1785
- ASTM D2241
- ASTM F2389.

Socket-type polyethylene fittings may be used for outside diameter-controlled polyethylene pipe. Pipe shall be welded together following:

- ANSI/American Welding Society (AWS) D1.1/D1.1M
- ASTM D2241

- ASTM D2855*.*

6.10.1.6 Trap Seal Protection

Where there is the possibility of loss of the seal in floor/funnel drain traps, a trap primer valve and a floor/funnel drain with trap primer valve discharge connections shall be installed.

6.10.1.7 Backflow Preventers

Backflow preventers of the reduced-pressure zone type shall be provided on all domestic water and fire protection lines serving the building.

6.10.1.8 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 water input rate shall follow applicable provisions of the ASME BPVC. 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.

6.10.1.9 Pressure-Reducing Values

Pressure-reducing valves shall be provided where service pressure at fixtures or devices exceeds the normal operating range recommended by the manufacturer. Wherever failure of a pressure-reducing valve could cause equipment damage or unsafe conditions, a pressure-relief valve shall be provided downstream from the reducing valve.

6.10.1.10 Water Hammer Arrestors

Water hammer arrestors shall be provided in the following locations:

- At each elevation change of every horizontal branch to fixture batteries

- At all quick-closing automatic valves (i.e., mechanical make-up supplies, drinking fountains, flush valves, single-lever control faucets, temperature regulating valves, dishwashers, return pumps, and similar)

- Each floor on each horizontal main for branches with and without individual fixture or battery water hammer arrestors, for both hot and cold water.

Water hammer arrestors shall comply with the Plumbing and Drainage Institute (PDI) Standard PDI-WH201-2006, *Water Hammer Arrestors,* ANSI/ASME A112.26.1M, or as required by code, and as recommended/required by the fixture/equipment manufacturer.

6.10.1.11 De-ionized Water System

Unless otherwise specified in the project criteria, the central de-ionized water system shall have a resistivity of greater than 10 megaohms (MΩ) 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 requirements for water used in microbiological testing. Type I water is typically prepared by reverse osmosis, then polishing it with mixed-bed de-ionizers (i.e., ion exchange process) and passing it through a 0.2 micron (µm) membrane filter.

Pipes and fittings for the de-ionized water system shall be polyvinylidine fluoride Schedule 80 or un-pigmented 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.

6.10.1.12 Hot and Cold Water, Non-Potable

The laboratory non-potable water supply shall be piped in Type K or Type L copper. Approved backflow prevention devices shall isolate the laboratory non-potable water system from the potable water system. The hot water supply runs shall be insulated, and hot water shall be re-circulated to conserve energy where feasible.

6.10.1.13 Culture Water System

Culture water system piping shall be constructed of Schedule 80 un-pigmented polypropylene and shall have no metal in contact with the water. The holding tank shall be lined with un-pigmented polypropylene. Transfer pumps shall be of solid un-pigmented polypropylene. Water shall be provided to each culture tank in constant overflow mode to keep the tanks aerated and carry away waste products.

6.10.2 Fixtures (Low Flow)

In an effort to promote water and energy savings, EPAct 1992 requires certain fixtures to be more water efficient. New water fixtures may not exceed the thresholds specified in the statute and relevant codes and standards, including the 2006 Uniform Plumbing Code and 2006 International Plumbing Code (IPC) (or most recent versions of these codes). EPA's WaterSense™ Program has also developed criteria for different types of low-flow fixtures; the relevant WaterSense standards are described below in the following paragraphs.

The toilet room hot water should be set at 105°F, or as required by the project criteria.

6.10.2.1 Dual-Flush Toilets

Dual-flush toilets have two types of flushes: one flush is standard and removes solids (full flush); the second is smaller and removes paper and liquids (reduced volume flush). In certain situations, it may be possible to retrofit current toilet models to dual-flush operation. Dual-flush toilets shall meet the following specifications:

- Full-flush water usage of 1.6 gallons per flush (gpf) or less
- Reduced volume flush water usage of 0.8 gpf to 1.1 gpf
- Effective flush water usage of 1.28 gpf.

The effective flush volume is the average flush volume when the toilet is tested in accordance with ASTM A112.19.2.

6.10.2.2 High Efficiency Toilets

High Efficiency Toilets (HET) flush at an effective flush volume of 1.28 gpf or less, which is 20 percent below that required by the current national standard of 1.6 gpf based on EPAct 1992. EPA's WaterSense program[19] developed a performance specification to recognize and label

[19] WaterSense is an EPA program that helps consumers identify water-efficient products and programs. The WaterSense label indicates that products and programs meet water efficiency and performance criteria.

tank-type HETs for residential and light commercial applications. The Implementing Instructions that accompany EO 13423 state that Federal agencies should consider specifying WaterSense products where applicable and feasible. In addition to increased efficiency, WaterSense HETs must also pass a rigorous waste removal performance test not required for other toilet fixtures. This ensures that efficiency does not come at the expense of performance.

Where practicable, the project plumbing engineer shall specify HETs. In situations where such equipment is not available, water usage of between 1.28 gpf and 1.6 gpf will be considered acceptable. However, where feasible and cost-effective, the most water-efficient unit that is commercially available shall be specified.

6.10.2.3 High Efficiency Urinals

In accordance with the October 8, 2009 WaterSense specification (which covers commercial as well as residential urinals), high efficiency urinals (HEU) that operate at 0.5 gpf or less shall be specified. HEUs shall be used on all new construction and major renovation projects. In addition, where technically feasible and cost-effective, the type of urinal that is commercially available and uses the minimum gpf shall be specified.

Waterless urinals shall comply with applicable provisions of ANSI Z124.9, ASME A112.19.19, and the IPC. Liquid refills and traps shall have minimum lives of 1,500 uses and 7,000 to 10,000 uses, respectively.

6.10.2.4 Lavatory Faucets

Per ASME A112, lavatory faucets at EPA facilities shall have a not-to-exceed flow rate of 0.5 gpm at a flowing water pressure of 60 psig. All faucets shall be equipped with aerators except where prohibited by local code or the International Plumbing Code (IPC).

Metered-valve faucets deliver a preset amount of water and then shut off. To control water usage, the preset amount of water can be reduced by adjusting the flow valve. ABAAS requires a 10-second minimum on-cycle time.

At all facilities leased by EPA, electronic sensors or adjustable metering, self-closing cartridges shall be installed on all lavatory sinks. Sensors shall be the Sloan “Optima” series or equivalent product acceptable to EPA.

Lavatory 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, and/or recessed far enough such that wheelchair-bound individuals who are without sensation will not burn themselves.

EPA facilities must reduce their water usage by at least 20 percent below the applicable commercial water use baseline (i.e., it is a prerequisite) to become LEED-NC 2009 certified. Facilities can earn additional points by decreasing their water use by 30 to 40 percent (or greater) below the commercial water use baseline. The baseline values for different types of plumbing fixtures are contained in the LEED Reference Guide. Current EPA policies require fixtures that in general meet or exceed the LEED-NC 2009 limits. ***(Water use reduction greater than 40 percent may also present an opportunity to earn Innovation in Design points, as described in the LEED Reference Guide.)***

6.10.2.5 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 fabricated from 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.

Faucets in laboratory workspaces shall have flow no less than 2 gpm and no higher than 5 gpm, unless otherwise dictated by project requirements.

6.10.2.6 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 cfm to 300 cfm, with an exhaust air duct connection at the top of the sink below the bench top.

6.10.2.7 Kitchen and Mop Faucets

At facilities leased by EPA, all faucets installed at kitchen sinks and janitorial mop-cleaning sinks shall use no more than 1.8 gpm at a flowing water pressure of 60 psig. Foot controls for kitchen faucets provide both water savings and hands-free convenience. The hot-cold water mix is preset, and the foot value turns the water on and off at the set temperature.

6.10.2.8 Showers

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 ABAAS and/or UFAS, as applicable.

A five-minute shower with a non-EPAct compliant conventional showerhead typically consumes 15 gallons to 35 gallons of water. High-quality, EPAct compliant replacement showerheads that deliver 1.0 gpm to 2.5 gpm can save 10 gallons to 22.5 gallons per five-minute shower, when used to replace conventional showerheads. A variety of spray patterns are available, ranging from misty to pounding and massaging. These showerheads typically have narrower spray jets and a greater mix of air and water than conventional showerheads, enabling them to provide what feels like a full-volume shower while using far less water.

Flow regulators on the shower controls and temporary cutoff buttons or levers incorporated into the showerhead reduce or stop water flow when the individual is soaping or shampooing, further lowering water use. When the water flow is reactivated, it emerges at the same temperature, eliminating the need to remix the hot and cold water.

Where commercially available, technically feasible, and cost-effective, showerheads shall have a maximum water consumption less than or equal to 2.0 gpm and meet all other requirements of the EPA's Final *WaterSense Specification for Showerheads*, dated March 4, 2010.

In addition, the showerhead or associated systems shall mix hot and cold water adequately to prevent scalding, which generally occurs at a water temperature greater than 110°F (or lower for sensitive populations such as children and elderly persons).

Flow restrictors are washer-like disks that fit inside showerheads, and were initially well-accepted due to their simplicity and low cost. However, facility operators have discovered that flow restrictors provide poor water pressure in most showerheads; hence, they shall not be used on EPA new construction and major renovation projects.

6.10.2.9 Drinking Fountains

At least one drinking fountain shall be provided on each block of space so that no building occupant 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, *Self-Contained, Mechanically-Refrigerated Drinking Water Coolers*. Electrical equipment shall be UL-listed. The refrigeration coils shall not be assembled using lead solder, and all components must bear the marking NSF 61, indicating the components are free of lead. All drinking fountains and locations for drinking fountains shall comply with applicable ABAAS provisions.

Self-contained drinking fountains shall meet the following specifications to minimize water consumption:

- The unit shall be capable of operating at a nominal temperature of 70°F (compared to the 65°F nominal temperature for conventional drinking fountains).
- Fiberglass insulation (minimum 1 inch thick) shall be installed on the piping, chiller, and storage tank to minimize heat gain and preclude condensation formation.
- An automatic timer shall be installed to shut off the unit during evenings and weekends.

Additional requirements for drinking fountains are as follows:

- The water storage tank shall be sized to hold at least 50 percent of the estimated hourly water demand.
- All drinking fountains shall also be equipped with an inlet strainer that can trap particles larger than 140 µm (or as required by local code).
- The refrigeration system shall use non-chlorofluorocarbon (CFC) refrigerants (e.g., R-134a) and be hermetically sealed.
- An internal adjustable stream regulator shall maintain delivered pressure between 20 psi and 90 psi (or as required by local codes and standards), except for supplies that require higher pressure.
- The unit shall also comply with applicable provisions of ANSI A117.1.
- The water cooler shall have a filling port for glasses or other beverage containers.

6.10.2.10 Janitor Closet Sinks

Janitor closets for cleaning equipment, materials, and supplies shall be provided on all floors. All janitor closets shall be equipped with a service sink with hot and cold water taps. Containment drains shall be plumbed for appropriate disposal of liquid wastes in spaces where water and chemical concentrate mixing occurs for maintenance purposes. Permanent signage shall be affixed, indicating prohibited items for disposal (based on presence/absence and type of on-site wastewater treatment and local sewer permit prohibitions and concentration limits).

6.10.3 Stormwater Drainage System

A complete stormwater building drainage system shall be provided for all stormwater drainage for roofs, plazas, balconies, decks, window wells, parking structures, parking garages, and similar (Note that this does not include stormwater managed by means of low impact development [LID] strategies described in Section 3.2 of this Volume). Clear water drainage (e.g., cooling coil condensate drainage, evaporation pan drainage, ice makers) and similar clear, non-chemically treated drainage shall discharge to the stormwater drainage system and not to the sanitary drainage system. In addition, unless granted an exemption by the EPA project manager, all projects shall consider the efficacy of disconnecting some or all drains from the storm drainage or sewer system and thus returning a portion or all of the total drainage for infiltration or for on-site beneficial uses.

All projects shall comply with the EPA's *Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act*, February 20089 (or most recent version)—in particular the instructions regarding maintaining the pre-development volume, rate, temperature, and duration of stormwater runoff at the site after the project is completed.

6.10.3.1 Stormwater Drainage Pipe and Fittings

The stormwater and associated vent system shall be designed in compliance with applicable local codes and standards. P-traps and house-traps shall only be provided on storm systems where required by code or by state or local authorities. Piping shall be service-weight, cast iron soil pipe with hub and spigot fittings and joints with elastomeric gaskets (by pipe manufacturer). Above-ground piping shall have hub-less fittings and joints (by pipe manufacturer), within 12 inches of each side of every joint where not superseded by code.

6.10.3.2 Stormwater Vent Piping and Fittings

Storm vent piping, where required for P-traps, sumps, interceptors, and separators, shall be service-weight, cast iron soil pipe with hub and spigot fittings and joints with elastomeric gaskets (by pipe manufacturer). Above-ground piping shall have hub-less fittings and joints (by pipe manufacturer). Where approved, Type K drain, waste, or vent (DWV) copper piping, with 95 percent tin/5 percent antimony solder joints, may be used.

EPA has issued a CPG for non-pressure pipe, i.e., pipe that can be utilized for drainage applications. Table 6-15 lists the CPGs for different materials of construction:

Table 6-15: EPA's CPG for Non-Pressure Pipe[1]

Products/Materials	Minimum Required Post-Consumer Content	Minimum Required Total Recovered Materials Content
Steel (manufactured using the BOF Process)	16%	25 - 30%
Steel (manufactured using the EAF Process)	67%	100%
HDPE	100%	100%
PVC	5% – 15%	25% – 100%
Concrete	Follow the Cement and Concrete CPG[2]	

1. Last updated August 15, 2006.
2. The Cement and Concrete CPG contains general recommendations for incorporating coal fly ash (e.g., from utility generating stations) and other pozzolans into concrete products. For example, the CGP recommends 20% to 30% fly ash content (maximum) so long as the requisite concrete properties are achieved.

CPG – Comprehensive Procurement Guideline; BOF – basic oxygen furnace; EAF – electric arc furnace; HDPE – high

Table 6-15: EPA's CPG for Non-Pressure Pipe[1]

Products/Materials	Minimum Required Post-Consumer Content	Minimum Required Total Recovered Materials Content

density polyethylene; PVC – polyvinyl chloride

6.10.3.3 Storm Drains

Rain-water (storm) drains include but are not limited to:

- Domed roof drains
- Secondary roof drains
- Hub and receptor drains (that do not receive floor drainage)
- Deck drains
- Drains in parking structures/garages
- Trench drains
- Window well drains.

Roof drains and planter drains in non-pedestrian/vehicle areas shall have high dome strainers. Receptors, hub drains, trench drains, and similar drains shall have dome-bottom strainers (in addition to pedestrian/vehicle grate strainers where required) to reduce splashing, increase free area, and prevent blockage by debris.

EPA facilities can earn points toward LEED-NC 2009 certification if they reduce potable water use for building sewerage conveyance by 50 percent or greater. This can be accomplished by using water-conserving fixtures and/or recycling non-potable wastewater streams on site (as detailed in the LEED Reference Guide).

6.10.3.4 Stormwater Equipment

Drains in parking structures and garage shall discharge to a oil/water/sediment separator prior to discharge to the storm sewer when required by code, state, or local authority. The drain body and frame-and-grate strainers shall be rated for expected traffic loadings (including dynamic loads) and shall include drain adapters, extensions, receivers, deck clamps, gravel stops and similar appurtenances as required by the design and by local codes. The drain strainer free area shall be equal to or greater than the free cross-sectional area of the calculated outlet pipe.

Drain strainers in pedestrian areas shall be heel-proof type. To prevent access by rodents:

- Every drain and system opening shall have ¼-inch or smaller strainer openings; and
- Discharges shall be elastomeric pinch valves or similar.

In general, drains shall be cast iron body-type with nickel-bronze strainers for finished pedestrian areas, aluminum domes for roof drains, and ductile iron or bronze finish for unfinished pedestrian areas. Rain-water drains and equipment room areas shall be equipped with large diameter strainers. Ramps shall be equipped with either trench drains or roadway inlets to manage drainage. Trap primers shall be provided for P-traps (where P-traps are required by code, state, or local authority).

6.10.3.5 Sump Pumps

Sump pumps shall only be used where gravity drainage is not possible. Only rain water, storm, and clear water drainage from the lowest floors of the building shall be connected to the sump pump; drainage from upper floors shall use gravity flow to the public sewer. Sump pumps shall be alternating duplex pumps, and shall be connected to the building's emergency power system.

The site foundation and sub-soil drainage system shall be perforated drain tile piping, wrapped in filter fabric (geotextile) and emplaced in washed gravel bed material. The drainage tile shall slope to the sump pump(s), as required by the applicable codes or a minimum slope of 1/8 inch per foot.

6.10.4 Sanitary Wastewater System

6.10.4.1 Sanitary Pipe and Fittings

A complete sanitary building drainage system shall be provided to service all:

- Plumbing fixtures
- Sanitary floor drains
- Kitchen equipment,
- Other equipment with sanitary, soil, or waste drainage/discharge.

The sanitary waste and vent system shall be designed in compliance with applicable codes and standards. Piping shall be service-weight, cast iron soil pipe with hub and spigot fittings and joints with elastomeric gasket (by pipe manufacturer). Aboveground piping shall have hub-less fittings and joints (by pipe manufacturer), with pipe supports that comply with code (generally within 12 inches of each side of each joint).

6.10.4.2 Vent Piping and Fittings

Piping shall be service-weight, cast iron soil pipe with hub-and-spigot fittings and joints with elastomeric gaskets (by pipe manufacturer). Aboveground piping shall have hub-less fittings and joints (by pipe manufacturer), or else consist of Type K DWV copper with 95 percent tin/5 percent antimony solder joints.

6.10.4.3 Sanitary Floor Drains

Sanitary floor drains shall be provided in multi-toilet fixture restrooms, kitchen areas, mechanical equipment rooms, and locations where interior floor drainage accumulates sanitary-type wastes (single-fixture toilet rooms do not require floor drains). In general, floor drains shall be cast iron body type with 6-inch diameter nickel-bronze strainers for public toilets, kitchen areas, and other public areas. Receptor drain outlets shall be at least two times the area of combined inlet pipe areas. Floor drains in equipment room areas shall be equipped with large diameter cast iron strainers, and parking garages shall require large diameter tractor grates rated for expected wheel loading. Trap primers shall be provided for all sanitary drains (floor drains, receptors, open site drains, hub drains, and similar) where drainage is not routinely expected, or is seasonal.

The facility system shall be plumbed such that only sanitary wastewater is managed through the sanitary sewer system. The system shall have no connections with floor drains or drain piping that is used for the collection of:

- Industrial wastewaters
- Wastewaters containing Clean Water Act Priority Pollutants
- Wastewaters that meet the definition of a RCRA hazardous waste.

Grease Interceptors

Grease interceptors shall be provided for all drains and fixtures that:

- Receive fats-, oils-, or grease-containing waste
- Are within 10 feet of the cooking battery and/or mop and service sinks in kitchen areas
- Are required to by the state health department and local authorities.

All grease interceptors shall be connected to the sanitary sewer system. Grease interceptors shall be sized in compliance with the requirements of the local sewer authority and with PDI Standard PDI-G101. Generally food grinders, vegetable cleaning sinks, fish-scaling sinks, meat-cutting sinks, and clear water wastes are prohibited by the local authority from extending to the grease interceptor. An individual solids separator must be provided for fish-scaling sinks.

6.10.4.4 Oil/Water/Sediment Separator

Floor drains and/or trench drains in vehicle repair garages shall discharge to an oil/water/sediment separator prior to discharge to the sanitary sewer. The most common configuration will consist of a triple basin system with or without a downstream laminar-flow, parallel plate coalescing separator for moderate to heavy oil loadings. Depending on the wastewater stream composition, additional treatment processes such as a vortex-type settling vessel,[20] activated carbon beds, or skimmers may also be required prior to discharge. Discharge limits will be specified in the applicable sewer authority pre-treatment permit. Refer to the *Environmental Management Manual* for additional environmental performance and compliance information.

6.10.4.5 Automatic Sewage Ejectors

Automatic sewage ejectors shall only be used where gravity drainage is not possible. Only sanitary drainage from the lowest floors of the building shall be connected to the sewage ejector; fixtures on upper floors shall use gravity flow to the public sewer. Sewage ejectors shall be non-clog, screen-less, alternating duplex pumps, capable of passing a 2-inch solid, with each discharge not less than 4 inches in diameter. They shall be connected to the building emergency power system.

6.10.4.6 Clear Water and Non-Clear Water Drainage

Storm rainwater, cooling coil condensate drainage, and similar clear-water drainage shall not discharge to the sanitary drainage system. Chemically-treated mechanical discharge from cooling towers, boilers, chillers, and other mechanical equipment shall discharge to the sanitary sewer system. Purified steam (i.e., from humidification processes) shall not be discharged to the sanitary sewer system.

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[20] For example, the vortex and oil baffle system installed to process stormwater drainage at EPA's New England Regional Laboratory in Chelmsford, Massachusetts.

6.10.5 Process Wastewater System

Process wastewater collection and treatment will depend on the specific facility's operations and discharge permit requirements. In general, EPA facilities that generate process wastewater streams will be laboratories. Discharge from shop area floor drains shall be, at a minimum, conveyed through an oil/water/sediment separator as outlined above. In certain cases (e.g., where solvents are used or the facility is located in a watershed with strict discharge limits), additional treatment such as chemical precipitation or activated carbon adsorption may be required to meet discharge limits.

EPA facilities can earn points toward LEED-NC 2009 certification if they treat at least 50 percent of wastewater to tertiary standards *and* infiltrate or use all of the treated effluent on site. "Tertiary treatment" standards are defined in the LEED Reference Guide.

Process wastewater treatment systems shall be designed to achieve compliance with the required discharge standards in:

- 40 CFR Part 403 or applicable local and state regulations and ordinances (pre-treatment discharges to POTWs)
- 40 CFR Parts 405 – 471 (direct discharges to waters of the United States).

All non-sanitary laboratory wastewaters are required to pass through an on-site water treatment system to control pH as well as other chemical and/or material constituents, before discharging to a municipal sewer system and local POTW. The system shall be designed and constructed in accordance with 40 CFR 403.5*,* the National Pollutant Discharge Elimination System, and the local POTW requirements (i.e., sewer connection permits and/or pre-treatment discharge authorizations). The system shall have the capability of automatic, continuous monitoring and recording of wastewater discharge flow, pH, and other constituents to conform with local POTW requirements. This typically will include continuous reading meters (e.g., for pH and temperature), and auto-composite samplers that collect hourly samples over a 12- or 24-hour period, for subsequent laboratory analyses.

System components, in particular the outfall to the sewer system, must 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.

Design of the on-site wastewater collection and pre-treatment system should consider alternatives for reuse, recycling, or other beneficial use of non-toxic wastewater streams (or waste streams that the POTW cannot accept in its system). As one example, an on-site wetlands might be used where feasible to remove heavy metals from wastewater while also storing and filtering stormwater runoff.

6.10.6 Natural Gas Supply

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

6.10.6.1 Service Entrance

Natural gas service utility piping entering the building shall be protected from accidental damage by vehicles, foundation settlement, or vibration. Wall penetrations shall be above grade and provided with a self-tightening swing joint located upstream of the building and wall penetration. Where wall penetration above grade is not possible, the gas pipe shall be encased in a Schedule 80 black steel, corrosion-protected, sealed and vented, gas pipe sleeve that extends from 10 feet upstream of the building wall penetration exterior (or excavation shoring limits if greater) to 12 inches (minimum) downstream of the building wall penetration. Gas piping shall not be placed in unventilated spaces, such as trenches or unventilated shafts, where leaking gas could accumulate and result in an explosion.

Gas piping shall not be run in any space between a structural member and its fireproofing. Pipelines shall be labeled in accordance with 29 CFR 1910.1200. Local gas utility and code requirements shall be followed.

6.10.6.2 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 exterior of the building.

6.10.6.3 Shutoff Valves

Earthquake-sensitive shutoff valves shall be provided for each gas entry, where required by local code.

6.10.6.4 Gas Piping within Building Spaces

Gas shall not be piped through confined spaces, such as trenches or unventilated shafts. All spaces containing gas-fired equipment, such as boilers, chillers, water heaters, and generators, shall be mechanically ventilated and include automated methane detectors and alarms connected to the BAS. Vertical shafts carrying gas piping shall be ventilated. Gas meters shall be located in a ventilated gas meter room, thus avoiding leakage concerns and providing direct access to the local gas utility. All gas piping inside ceiling spaces shall have plenum-rated fittings, and no gas valves (whether concealed or accessible) shall be installed above ceilings. All diaphragms and regulators in gas piping must be vented to the outdoors.

Requirements concerning natural gas supply and distribution systems for laboratories are contained in Section 6.8.2.

6.10.7 Fuel Oil Storage and Supply

6.10.7.1 Fuel Oil Piping Systems

Fuel oil piping systems shall be double-walled containment pipe (pipe-in-pipe) when indoors, outdoors, or buried, and shall be Schedule 40 black steel or black iron piping. Fittings shall be of the same metal or alloy as the pipe material. Valves shall be bronze, steel, or iron and shall be screwed, welded, flanged, or grooved. Duplex fuel oil pumps with basket strainers and exterior enclosures shall be used for pumping fuel oil to fuel-burning equipment.

6.10.7.2 Underground Fuel Oil Storage Tanks

Underground fuel oil storage tanks (USTs) shall be of double-walled, non-metallic construction (e.g., fiberglass), or contained in lined vaults. USTs shall be sized for actual storage volume for sufficient capacity to provide a minimum of 48 hours of system operation under emergency conditions (72 hours for remote locations). A monitored and alarmed liquid and vapor leak detection system shall be provided in the interstitial space between the two tank walls (vaults shall be equipped with monitoring wells and/or sumps). Each UST system shall also have an automatic leak detection probe that continuously measures the liquid level (and hence volume) of product in the tank and provides a local visual or printed readout, as well as a data signal to the

BAS. Each UST shall be equipped with a spill catch basin and an overfill sensor that triggers a visual/audible alarm, consistent with 40 CFR Part 280).

6.10.7.3 Aboveground Fuel Oil Storage Tanks

All aboveground fuel oil storage tanks (AST) shall be carbon steel or fiberglass of suitable strength for the application (i.e., material being stored, storage pressure, etc.). In accordance with the secondary containment requirements in 40 CFR 112 and NFPA 30, Chapter 22, all ASTs shall be double-walled and equipped with an interstitial sensor similar to USTs. ASTs shall be equipped with overfill alarms similar to USTs. *Note that ASTs may need to meet additional requirements based on the facility's Spill Prevention, Control, and Countermeasures (SPCC) Plan, as required by 40 CFR 112—refer to the Environmental Management Manual for additional specifications on SPCC plans.*

Additional information regarding petroleum USTs and ASTs is provided in Volume 4, Chapter 5 of this Manual.

6.10.8 Emergency Eyewash Units and Safety Showers

6.10.8.1 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 space, 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 shall 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. Water for the units shall be supplied by the potable-water system. The temperature of flushing fluid for the emergency units shall be tepid (between 60°F and 95°F). Emergency eyewash units shall be provided with sanitary drains. Discharge from emergency eyewashes should not impinge on powered electrical equipment.

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 clearly identified with a highly visible sign. Safety equipment must meet ABAAS accessibility requirements.

6.10.8.2 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 similar to 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 pull bar connection. Discharge from emergency showers should not impinge on powered electrical equipment.

Design, operation, flow rates, and similar characteristics shall meet the criteria in ANSI Z358.1. 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°F to 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, and identified with a highly visible sign. 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 generally 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. Safety equipment must meet ABAAS accessibility requirements. Refer to Chapter 4 of the *Safety Manual* for additional information.

Emergency safety showers located on the hinge side of exit doors must be clear of the door swing and at least 6 feet away from any electrical devices (switches, outlets, panels, etc.) Laboratory walls adjacent to the showers shall be water- and mold-resistant construction (e.g., mold-resistant gypsum, paperless gypsum board, or coated with a waterproof coating).

EPA recommends that a modesty curtain(s) be provided at each safety shower location.

6.11 Solid Waste Handling and Recycling Equipment

Management of hazardous waste shall comply with Subtitle C of RCRA (Refer to Volume 4 of this Manual). Management of non-hazardous solid waste shall comply with Subtitle D of RCRA. In addition, each building must accommodate a non-hazardous 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 (at a minimum) 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 indicated in Chapter 4 of this Manual.

EPA facilities are required (i.e., by prerequisite) to set aside sufficient storage space for recyclables (e.g., paper, cardboard, glass, metal, and plastic) to become LEED-NC 2009 certified. Equipment such as balers, can crushers, etc. reduces the volume of recyclables and therefore aids in maximizing available on-site storage space.

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.

6.11.1 Compactors

Compactor systems provided pursuant to this section shall:

- Consist of a base, receiver chamber, and a horizontal hydraulic ram
- Be designed specifically for the processing of municipal solid waste from office or commercial/industrial application, as applicable

- Be compatible with either a 30 cubic yard (yd^3) or 40 yd^3 standard roll-off box (capacity will be specified by EPA on a project-specific basis).

Compactors shall be easy to load from the ground level and the dock level. Power units shall be located within the confines of the packer frame. Electrical connections to compactors shall be accomplished in accordance with the NFPA 70.

Framework is required to anchor the system hopper and, in some cases, provide a platform for loading trash into the compactor. The frame shall be constructed of appropriate carbon steel alloys and designed to support the weight of the equipment and also withstand any dynamic loads imposed by the compactor ram cycling. Replaceable PE wear bars shall be provided on all sides, top, and bottom of the platen to promote quiet and near frictionless operation. Permanent rails to anchor the container shall be installed.

The electrical and hydraulic system for the compactor must have, at a minimum, the following features:

- Programmable logic controller and power unit
- EMERGENCY STOP button, that is accessible from all operator locations
- Automatic single cycle
- AUTO/MANUAL selector switch
- Key lock ON/OFF switch
- 80 percent full and 100 percent full warning lights
- Automatic shutdown with auto safety retract
- Hydraulic fluid level and temperature gauges
- Fluid-filled pressure gauge
- Fluid inlet strainer
- Low oil shutdown.

Stationary compactors shall also conform to the safety, installation, and O&M requirements of ANSI Z245.2 and ANSI Z245.21 (most recent editions). Compactors shall be equipped with machine guards and safety interlocks to minimize risk of worker injury. Interlocks should be designed such that they cannot be overridden.

6.11.2 Platform Scales

Platform or floor scales shall be electronic (i.e., no mechanical parts) and capable of reading weights of up to 2,000 pounds with an accuracy of ± 0.1 percent (compared with a reference standard). The scale shall include a programmable liquid crystal display unit with push button functions that is capable of displaying weights in pounds and in metric units. The scale platform shall be three-part galvanized epoxy coating and have heavy-duty stainless steel load cells.

6.11.3 Balers

Balers shall be vertical, down-stroke type machines capable of producing a minimum 1,000 pound bale of used cardboard containers. Balers shall have the following features:

- Heavy-duty hydraulic ram, hydraulic fluid reservoir, pump, and piping/hosing or other necessary appurtenances
- Hydraulic fluid pressure gauge
- Electric motor and necessary wiring and appurtenances
- Automatic wire-tying machine
- Heavy-duty steel frame, enclosure, and safety gate
- Motor overload protection and full chamber warning light
- Leaf-type or equivalent ejector mechanism
- Cycle time of one minute or less
- Wear pads to minimize metal-on-metal contact
- Side-mounted electrical control panel
- Safety switch that prevents operation unless the safety gate is fully closed.

Balers shall also conform to the safety, installation, and O&M requirements of ANSI Z245.2 and ANSI Z245.21 (most recent editions). Balers shall be equipped with machine guards and safety interlocks to minimize risk of worker injury. Interlocks should be designed such that they cannot be overridden.

7. ELECTRICAL REQUIREMENTS

7.1 General Requirements

7.1.1 Code Compliance

All work done in this section shall comply with the applicable requirements of the most recent edition of the following codes and references:

- The Architectural Barriers Act Accessibility Standards (ABAAS)
- American National Standards Institute (ANSI)
- American Society of Heating, Refrigerating and Air-Conditioning (ASHRAE) 55
- ASHRAE 62.1
- ASHRAE 90.1
- ASHRAE 189.1P
- Federal Energy Management Program (FEMP)
- Lightning Protection Institute 175
- National Fire Protection Association (NFPA) 70 or National Electric Code (NEC)
- NFPA 72
- NFPA 90A
- NFPA 101
- NFPA 110
- NFPA 111
- NFPA 780
- National Electrical Safety Code (NESC)
- 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 ADA/ABAAS and Uniform Federal Accessibility Standards (UFAS), Sections 2, 3, 4, and 4a, respectively, of the Architectural Barriers Act of 1968, as amended
- National Association of Corrosion Engineers (NACE) International Standards
- Standards of the National Electrical Manufacturers Association (NEMA)
- International Electrical Testing Association (NETA)
- 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 (2005 or most recent version)

- Underwriter's Laboratories (UL)

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 UL or a similar Occupational Safety Health Administration (OSHA)-certified Nationally Recognized Testing Laboratory (NRTL) acceptable to the EPA. When codes conflict, the most stringent standard shall govern.

7.1.2 Design Calculations

The A/E shall prepare calculations that show the available short-circuit currents at each bus and the voltage drop for each major cable run. The A/E shall provide system load calculations for switchgear, switchboards, panelboards, and motor control centers (MCCs). The A/E shall provide product and photometric data sheets for all lighting fixtures specified in the design and lighting calculations.

7.1.3 Electrical Studies and Testing

Short Circuit and Coordination Study

The A/E shall include in the specifications, requirements for a short circuit and coordination study, to be provided by an independent testing agency. For minor projects, the A/E shall determine the need for either study, and document findings in the Basis of Design Report. The A/E shall modify the standard specification to conform to the project requirements. The following requirements shall be added to the standard coordination study specification:

> "Plots shall include the ground fault protective device settings along with the other overcurrent settings. Plots, which include ground fault protective devices, shall also include a typical 20-ampere downstream circuit breaker, and a sampling of other downstream devices, to show where coordination exists or does not exist between devices. Ground fault settings shall attempt to coordinate with downstream devices to the maximum extent practicable."

Electrical Equipment Testing Requirements

All major items of electrical equipment shall be tested in accordance with NETA standards, by an independent testing agency. The specification section for each item of major equipment shall indicate the specific NETA section which specifies the testing to be performed. The A/E shall determine the appropriateness of all components of the tests, and add or delete criteria, modify, or limit the standard test, as deemed appropriate. Testing specification for switchgear and switchboards shall require that the NETA standard for switchgear and switchboards have the section relating to inspection of bolted connections, replaced with the following: "Inspect all bolted electrical connections for high resistance. Check tightness of all bolted electrical connections by using a calibrated torque wrench. Each bolt shall be individually tested and individually marked to indicate that it has been tested. Refer to manufacturer's instructions or NETA Acceptance Testing Standards for proper torque levels."

Electrical System Function Testing

For electrical systems with functions, which are not adequately covered by the above standard tests such as control systems, the A/E shall determine and specify system tests required and the acceptance criteria. NETA Section 8 "System Function Tests" shall be used as the basis of this requirement. The A/E shall reference a specific test code or procedure. If none is available, the A/E shall either:

- Provide and include in the specifications, a test procedure to verify proper operation of the system, or
- Provide and include in the specifications, lists of the functions that are to be tested, and require the testing organization to determine the appropriate testing procedures and submit them for approval.

7.1.4 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.

7.1.5 Energy Efficiency 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 ASHRAE Standard 90.1-2007, 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. When procuring energy-consuming products (e.g., lighting, motors, etc.) for EPA, the products shall be either ENERGY STAR or FEMP-designated products wherever feasible and cost-effective, as outlined herein (EPAct 2005, Section 104).

LEED-NC 2009 strongly encourages facilities to maximize their energy performance. EPA facilities that comply with the EO 13423-required 30 percent improvement over ASHRAE 90.1-2007 can receive at least 10 points (and as many as 19 points), depending on the level of energy savings compared to a specified baseline value. Strategies and technologies covered in this section aid in improving energy performance and reducing total energy consumption.

Local Energy Conservation Programs

The local utility company shall be contacted to find the most recent information on 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.

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.

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.

7.1.6 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.

7.1.7 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 horsepower (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.

7.1.8 Handicapped Accessibility Requirements

The facility shall comply with the electrical requirements of the ABAAS 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.

7.1.9 Material and Equipment Standards

All specified materials and equipment shall be standard products from 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.

7.1.10 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. All equipment and material shall be suitable for the environment in which it 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.

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.

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.

Saltwater Atmosphere

Only hot-dipped galvanized steel and polyvinvl chloride (PVC) conduit and fittings are acceptable for buildings in salty weather areas.

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. Use of engine block heaters shall also be considered where warranted.

Noise

Noise mitigation shall be provided for equipment such as transformers and generators.

7.1.11 Facility Maintenance and Operations

The design shall be reviewed by qualified persons for maintainability, including life cycle costs and equipment standardization. In addition, the Project Electrical Engineer shall:

- Ensure the minimum possible impacts to existing engineering and maintenance resources.
- Determine and identify training requirements, using the manufacturer's recommendations.
- Ensure that operations and maintenance manuals requirements are clearly stated in the specifications.
- Ensure that warranty and guarantee document requirements are clearly stated in the specifications.

- Establish requirements for detailed systems testing, adjustment, and balancing and associated documentation.

- Ensure that adequate accessibility and equipment clearances for maintenance and repair or replacement of components is provided.

- Furnish and/or supply specifications for replacement materials, spare parts, and specialized tools, for maintenance of equipment.

- Address other maintenance considerations such as access, storage, component maintainability, and operating parameters.

7.2 Primary Distribution

7.2.1 Duct Banks 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 Electrical Engineer for approval within 10 calendar days after contract award. The minimum conduit size for primary voltage cables shall be 4 inches. On multiple conduit duct banks for primary distribution systems and for the emergency power distribution system up to the emergency distribution switchgear, 25 percent and not less than one spare empty conduit shall be provided. Spare empty conduits for other critical equipment feeders, like the central HVAC equipment, shall be provided as directed in the program of requirements (POR) or required by the Project Electrical Engineer.

Underground conduit for circuits rated 600 volts or higher shall be encased in concrete. Multiple duct banks where the heat produced by adjacent circuits affect the current carrying capacity of each individual circuit shall be encased in concrete.

7.2.2 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.

7.2.3 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.

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, under built 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 NESC (ANSI Standard C2).

7.2.4 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).

Liquid-Filled Transformers

Liquid filled transformers shall be used outdoors and for below-grade vault construction. All liquid transformers shall be certified as free of PCBs by the manufacturer. Where silicon or oil-filled transformers are used, the transformers and ancillary systems must be designed to comply with all spillage containment and electrical code requirements.

Network Transformers

Where continuity of service is critical and where even a momentary disruption of service due to the loss of a single incoming feeder cannot be tolerated, then network transformers shall be considered. Network transformers shall be liquid-filled, kilovolt-ampere (kVA) rating as required, with copper primary and secondary windings. Transformers shall be equipped with provisions for fans and/or dual temperature ratings to increase the rated capacity and shall be provided with sufficient contacts to permit the remote monitoring of the status of the network protector, temperature and pressure in the enclosure and other components recommended by the manufacturer. In addition, transformers shall be provided with voltage taps ±2.5 percentage with on-load tap changer.

Dry Type

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 (dB) 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 electrical designer shall consider the use of shielded isolation transformers for sensitive computer and other electronic equipment loads.

Outside Substations and Transformer Installations

In addition to the requirements above, outside substations and transformers shall meet the requirements in the most recent edition the NEC, Article 450 and applicable local utility company substation construction standards.

7.2.5 System Redundancy

A risk/benefit analysis should be performed to justify added capital costs for system redundancy. Facilities with operations requiring uninterruptible power service shall be provided with permanent generators, of sufficient capacity to provide minimum sustaining power for those operations and for essential safety systems (e.g., emergency lighting, fire alarms).

7.3 Service Entrance

7.3.1 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.

7.3.2 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.

7.3.3 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 duct banks 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 most recent 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.

7.3.4 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 NFPA 70. 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.

7.3.5 Metering

Where medium voltage power is brought to the facility, electrical energy metering (kilowatt-hour [kWh]) shall be furnished at each substation of 500 kVA or greater capacity. Demand metering (kilowatt demand) 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. In accordance with §103 of EPAct 2005, advanced metering of electricity must be provided at all Government facilities by October 1, 2012 (unless the operator can demonstrate that such metering is not practicable at that location). Advanced metering is defined in the statute as metering systems that collect data at a minimum hourly frequency and automatically report the data to a central location at least daily.

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.

7.3.6 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 a panelboard or switchgear. 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.

All service entrance equipment shall have copper busing. If the main service consists of switchgear, 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.

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.

7.3.7 Surge Protection Devices

Surge protectors within the scope of this guideline should normally be of the parallel, rather than series type. Parallel surge protectors are connected in parallel with the circuit and operate when a transient voltage exceeds a preset limit. Parallel surge protectors have little interaction with the circuit under normal conditions. Parallel surge protector connections might be in-line (with effectively no lead wire length) or as a ‘T’ with some lead wire length. The in-line approach might be ampacity limited. Series surge protectors are connected in series with the circuit and must be capable of carrying the circuit’s full load current. Also, loss of the series surge protector will mean loss of power to all downstream equipment. For this reason, series surge protectors are usually used to protect individual loads and usually include some level of filtering also.

Apply surge protection in a multiple layer approach. The preferred design approach is to install a device at the service entrance and provide additional layers of protection at load centers, panelboards, and MCCs. Critical loads downstream of the distribution panels should have an additional level of surge protection as shown above. It is not necessary to install a surge protector on every panelboard in a facility; the selection of which panelboards should have surge protection depends on the importance of the loads served by each panelboard. HVAC equipment usually contain electronic controls that are sensitive to surges. Lighting electronic ballasts often are equipped with internal surge protection.

The most important surge protector evaluation criteria are:

- Listing in accordance with UL 1449, Standard for Transient Voltage Surge Suppressors, Second Edition.
- UL 1449 surge suppression rating.
- Maximum continuous overvoltage rating.
- Maximum surge current rating.
- Repeated surge current withstand capability.
- Modes of protection.
- Internal fusing characteristics.
- Installation capability.
- Warranty.
- Price.

The maximum continuous overvoltage rating (MCOV) is the rated voltage that can be applied to the MOV elements without having the surge protector start to operate. Table 7-1 lists the preferred MCOV rating for surge protectors. Lower MCOV ratings can be used provided that the manufacturer provides documentation of the surge protector performance during voltage swell events. Temporary overvoltages cause a large proportion of the total surge protector failures.

Table 7-1: Minimum Recommended MCOV Ratings

Alternating Current (AC) Power System Voltage	Minimum MCOV Rating
Single-Phase	
120	150
120/240	300/150
Three-Phase Wye	
208Y/120	300/150
480Y/277	600/320

Source: Tri-Service Electrical Working Group (TSEWG), 2008

Table 7-2 provides the minimum allowed surge current ratings per phase or per mode of protection. The surge current ratings have been selected based on ensuring an adequate margin for higher-than-expected surges due to nearby lighting strikes. Higher surge current ratings can be selected provided there is not a significant cost difference.

Table 7-2: Maximum Allowed Surge Current Rating

AC Power System Location	Minimum Surge Current Rating Per Phase or Per Mode of Protection
Service Entrance	200,000 amperes
Sub-Panels	100,000 amperes
Critical Loads	100,000 amperes

Source: Tri-Service Electrical Working Group (TSEWG), 2008

The surge current ratings specified in Table 7-2 apply regardless of whether the facility is located in a high, medium, or low exposure area (as defined by IEEE C62.41). The selected minimum surge current values are based on the following rationale:

- The values are high enough to ensure protection in high exposure areas.
- The values are not so high that lower exposure areas are over-protected.
- This approach does not force each designer to decide if a given facility is located in a high, medium, or low exposure environment.

UL 1449, Table 34.2, provides the various test configurations to provided different modes of protection. The total possible modes of protection depend on the system design and voltage level.

For single phase and three phase wye connected systems phase-to-neutral and neutral-to-ground modes of protection are recommended. Phase-to-ground protection will be important if the grounding system is of poor quality or (as in other countries) the neutral and ground are not connected. By protecting both the neutral and ground paths, any differences in potential between the two points will still be protected by surge events. Phase-to-phase protection is not needed for wye-connected systems provided that the other modes of protection are provided. For delta connections provide phase-to-phase and phase-to-ground modes of protection.

UL 1449 listing provides assurance that the surge protector can be applied safely. Some older surge protector designs could overheat and catch fire after an MOV degrades to the point that it continuously conducts current. Newer designs often individually fuse each MOV. In addition, a fuse might be installed for each separate mode of protection. If the selected surge protector has this type of fuse arrangement, verify with the manufacturer the overcurrent characteristics of the fuse when exposed to transient surge currents.

Surge protectors covered by this guideline should normally be of the parallel type. The surge protector size and installation method are important evaluation considerations. If the surge protector enclosure is over-sized, it might not fit near the required location, thereby causing the lead length of the connecting conductors to be excessive, which increases the let-through voltage.

A minimum 5 year full-replacement warranty is required. Longer warranty intervals are desirable.

7.4 Interior Electrical Systems

7.4.1 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,. 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.

7.4.2 Equipment Rooms and Closets

All substations, switchgear, switchboards, transformers, and, in general, panelboards, shall be installed in dedicated electrical rooms or closets. The electrical rooms shall be vertically stacked and physically separated from telecommunication equipment rooms and closets. The rooms shall be accessible from public corridors or lobbies and not via any other room. In special cases, such as tenant leased areas and areas with heavy concentration of electrical loads (kitchens, computers, communications equipment rooms, etc.), transformers and panelboards may be located in other rooms or areas near the load served.

Avoid routing pipes through electrical rooms or closets when economically sensible. Pipes or mechanical ducts shall not be routed directly above electrical equipment. Electrical outlets and lighting in electrical rooms and electrical closets shall be connected to emergency or standby power, if available. Branch circuits supplying emergency power for lighting and receptacles in substation rooms shall not supply emergency lighting in any public area. Equipment that is a part of the emergency power system (other than lights and receptacles, as noted above) shall not be located in substation rooms.

Each electrical room and electrical closet shall have at least one receptacle installed in it. All walls of electrical rooms and closets shall be painted a light color. Electrical rooms containing substations or switchgear shall be sized to provide clear space around the equipment of not less than 6 feet in front and 3 feet-6 inches in the rear and at the ends. Adequate egress shall be provided for the installation and removal of equipment. Where columns are within the rooms, they shall not encroach on the required space around equipment.

Electrical closets shall be provided in adequate quantity, size, and location to allow for top and bottom conduit entry and exit from the closet. Electrical rooms and closets shall be located central to the loads served. Floor, wall, and ceiling space shall be provided in electrical closets for future conduit and equipment.

Floor mounted equipment such as switchgear, switchboards, MCCs, and transformers, shall be placed on concrete pads. For switchgear and motor control centers, a pair of steel “C” channels shall be embedded in the pads. Channels shall be flush with or slightly above the top surface of the pad. Channels shall be level along their entire length, and the front channel shall be level with the rear channel. The location of the channels shall be per equipment manufacturer’s recommendation.

7.4.3 Raceways

All electrical wiring shall be installed in conduit or raceway or shall be otherwise physically protected in accordance with NFPA 70. Conduit shall be at least ¾ inch. The distribution of electrical power from the main switchboards should extend to vertical risers that serve electrical closets (aligned vertically) located in the core at each floor, and from the closets power should be distributed horizontally either through the access floor or (in areas not equipped with access flooring) within the ceiling cavity.

Service Entrance Conduit

Service entrance conduit shall be provided as permitted by NFPA 70 for the intended purpose, and shall be enveloped in a minimum of 2 inches of concrete encasement. An empty spare conduit shall be provided up to the service entrance disconnect.

Flexible-Metal Conduit

Liquid-tight flexible-metal conduit shall be used for connections to meters, transformers, pumps, and other equipment, as required by NFPA 70 and local codes, where vibration or movement can be a problem and where there is a need for protection from liquids, vapors, or solids.

Rated Assemblies

Raceways that penetrate fire-resistance rated assemblies shall be noncombustible. Penetrations shall be sealed to maintain the established fire resistance ratings as defined by an NRTL (such as UL). Use of ‘through-penetration” first stop systems is recommended.

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 (2¾ 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.

Plenums, Ducts and Other Air-Handling Spaces

All wiring shall be in accordance with NFPA 70, 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 an NTRL (such as UL) as having adequate fire-resistant and low smoke-producing characteristics.

Raised Access Floor

The standard option for delivering communications services in Federal buildings is by laying the cable in a tray for main runs and then branching directly on the floor slab below the raised access flooring system.

7.4.4 Cables (Electrical)

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.

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 non-linear loads 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 non-linear loads, 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.

7.4.5 Junction Boxes

Boxes for interior electrical systems shall be hot-dipped galvanized steel or malleable iron and shall be compatible with the raceway system. Cover plates for receptacles, switches, and boxes shall be stainless steel or brushed aluminum.

7.4.6 Cables (Communications)

The configuration and type of the voice and data cabling distribution systems shall be developed at the earliest stages of design, since the space requirements are so significant and widespread. System requirements are user generated and are generally translated into distribution system requirements by a Registered Communications Distribution Designer.

7.4.7 Switchboards and Panelboards

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.

At the main switchboards, provide spare over-current devices and bus extension for a 25 percent spare ampacity. At the panel boards provide spare breakers for a 25 percent spare ampacity for lighting panels and 50 percent spare ampacity for all other panels.

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. 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.

All distribution panels serving fluorescent fixtures, laboratory room distribution panels, and any other panels serving non-linear loads shall be UL-listed and labeled for non-linear loads.

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.

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 NFPA 70 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.

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 electrical design professional to consult with EPA very early in the electrical design (such as during the conceptual design phase) to enable EPA to indicate and designate where shunt trip breakers are required in each specific facility that is being designed. Locations of shunt trip breakers should be coordinated with the zoning of the fire sprinkler system. (Note: The activation of a fire sprinkler 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.)

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 non-linear loads. Each laboratory module shall be provided with uninterruptible power supply (UPS) power from a panelboard dedicated to critical power devices. The UPS power panelboard may serve more than one laboratory module.

Emergency Power Off Button

Each laboratory module and computer room protected by sprinkler systems shall have an EPO button by each main exit-access door to 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 laboratory module and each UPS circuit into the laboratory 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 airflow in the lab module when an EPO button is activated.

7.4.8 Motors and Ancillary Systems

Comply with the EISA 2007 requirements. Specify electric motors that meet or exceed efficiencies shown in Table 7-3 (unless stricter standards are issued by FEMP in the future). The new law grants two exceptions to higher efficiency minimums: one is for Subtype 1, NEMA Design B motors sized between 200 and 500 hp, which need only EPAct 92 efficiency ratings, MG1-2006, Table 12-11. The same exception is made for fire pump motors.

Table 7-3: Performance (Efficiency) Requirements for Random-Wound Electric Motors Rated at 600 Volts or Less

Motor Size (HP)	Open, Drip-Proof (ODP)			Total Enclosed, Fan-Cooled (TEFC)		
	6-pole (1,200 rpm)	4-pole (1,800 rpm)	2-pole (3,600 rpm)	6-pole (1,200 rpm)	4-pole (1,800 rpm)	2-pole (3,600 rpm)
1	82.5	85.5	77.0	82,5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	93.6
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4
250	95.4	95.8	95.0	95.8	96.2	95.8
300	95.4	95.8	95.4	95.8	96.2	95.8
350	95.4	95.8	95.4	95.8	96.2	95.8
400	95.8	95.8	95.8	95.8	96.2	95.8
450	96.2	96.2	95.8	95.8	96.2	95.8
500	96.2	96.2	95.8	95.8	96.2	95.8
Nominal Efficiencies for Induction Motors Rated Medium Voltage – 5 kV or less (Form-wound)						
250 – 500	95.0	95.0	94.5	95.0	95.0	95.0

HP – horsepower; kV – kilovolt; rpm – revolutions per minute

Measure in accordance with NEMA MG1-1998, Motors and Generators, and IEEE 112 Test Method B.

This specification is for general-purpose, single-speed, polyphase induction motors. Some applications require definite-purpose, special purpose, or special mounted polyphase induction motors. A motor meeting the efficiency levels of this specification is usually available for these applications also.

Motors that meet the required efficiency levels carry the NEMA Premium™ label, a program sponsored by the NEMA and endorsed by the Consortium for Energy Efficiency. The MotorMaster+ data base list motors by manufacturer and model number, grouped by size (HP) and type. Within each group, the highest efficiency motors are listed first. All models shown above the line labeled “Premium Efficiency – NEMA Table 12-12” meet the requirements of this specification. In many cases, purchasing even higher-efficiency motors can be cost-effective at average federal electricity prices. Cost-effectiveness will increase where there are higher electricity prices or peak demand charges. Buyers should note that motors labeled “energy efficient” will not meet these performance requirements and that only “Premium Efficiency” motors achieve the levels specified.

Use ENERGY STAR-qualified and FEMP-designated performance requirements for all energy-consuming products and systems. Exceptions to requirements through a written finding that no ENERGY STAR-qualified or FEMP-designated product is available to meet the functional requirements, or that no such product is life-cycle cost-effective for the specific application.

Motor Starters

Minimum starter size in motor control centers shall be Size 1. Control circuit voltage shall be 120 volts connected ahead of each starter via fused control transformer. Reduced voltage starters may be used for larger motors to reduce starting kVA. Time delay relays shall be incorporated in the starters or programmed in the building automation system to reduce inrush currents on the electrical system.

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 under voltage protection when used with momentary-contact pushbutton stations or switches and shall have under voltage 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, non-fused 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 (VFD) units shall be considered for larger HVAC equipment loads, and for other motor loads as feasible. See Chapter 6, *Mechanical Requirements*, of this Manual for equipment to be used with VFDs.

Control Equipment

Control equipment shall comply with the NEMA, Industrial Controls and Systems (ICS) standards, NFPA 70, and with UL 508. Single-phase motors may be controlled directly by automatic control devices of adequate rating. Automatically controlled poly-phase motors and all poly-phase motors rated greater than 1 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 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.

Shop Equipment

On shop equipment applications where injury to the operator might result if motors were to restart after power failures, provisions shall be made to prevent machines from automatically restarting upon restoration of power.

Fan Motors

Motors shall be sized according to properly calculated brake horsepower (bhp) fan requirements.

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.

Motor Control Centers

Where several motors (all of larger-than-fractional horsepower) are located in one room or space, a MCC 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. At MCCs provide space and capacity for 35 percent spare amperage.

Variable Frequency Drives

VFDs are now in general use on all projects by virtue of their contribution to the energy efficiency of the project. They also generate harmonics that are injected into the secondary power distribution system and need to be minimized using filters tuned to the peak harmonic generated by the drive. VFDs shall utilize a minimum 12-pulse, pulse width modulation, design because of their low harmonic output, excellent power factor and high efficiencies. VFDs shall be specified with passive harmonic filters. VFDs shall also be specified with isolation transformers where required.

Specify thermal sensors that interlock with the VFD control circuit for additional solid-state motor protection for motors running at low speeds and subject to overheating. This is in addition to the standard over-current protection required.

Use the most current version of NEMA publication, "Application Guide for AC Adjustable Speed Drive Systems" to assist in proper selection and application of cables and motors for VFDs.

7.4.9 Grounding and Protection

General Requirements

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: (1) the general facility grounding system that is connected to the building structure and other systems, and (2) 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 green with a yellow stripe. Every panelboard and switchboard in the facility shall be provided with a ground bus.

Isolated Grounding of Laboratories

All laboratory building modules shall be connected to the isolated grounding system. 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 NFPA 70, Article 250.

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 Project Electrical Designer to consult with EPA concerning any special requirements above those required by NFPA 70. All special ground fault requirements above those required by NFPA 70 shall be incorporated into the facility design.

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 NFPA 70, Article 620, Volume 3 of the EPA Facilities Manual, *Safety, Health, and Environmental Management Manual: Safety and Health Requirements* (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 semi-annually. 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.

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.

7.4.10 Laboratory Power Requirements

Duplex convenience outlets shall be laboratory standard grade, 20 amperes, 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:

- 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.
- Electrical outlets shall be located near the equipment to be powered; the exact location of equipment and outlets shall be determined by EPA 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 NFPA 70 Table 250.122.
- Laboratory panel boards shall be provided as specified in Section 7.4.7 above. Each laboratory panel board 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 NFPA 70, Article 645.10. The disconnecting means shall also disconnect the battery from its load.
- Using a dedicated room for a single UPS system that supplies computer room and lab module equipment, is recommended.

7.5 Lightning Protection

7.5.1 Scope of Design

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. Refer to Section 7.3.7 for surge protection requirements.

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.

7.5.2 Master Label

For buildings or 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 175. All cables, lightning rods, and accessories shall be copper. All connections and splices shall be of the exothermic weld type.

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 EPA.

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.

7.6 Cathodic (Anti-Corrosion) Protection

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 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. 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 three years' experience with similar installations. The cathodic protection design, as a minimum, shall comply 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.

Any existing metallic underground storage tanks (USTs) shall be cathodically protected (new USTs must be fiberglass or non-metallic construction). Refer to Chapter 5 of the EPA Facilities Manual Volume 4, *Safety, Health, and Environmental Management Manual: Environmental Management Requirements* (Environmental Management Manual) for additional requirements concerning USTs.

7.7 Lighting Systems

7.7.1 Interior Lighting

Required Illuminance Levels

The A/E shall design all projects so that the work required in the Construction Documents incorporates all relevant requirements as set forth below. The minimum acceptable levels of maintained general overhead illuminance shall be as indicated below in Table 7-4 for the particular areas. The maximum illuminance level shall be no greater than 115 percent of the minimum level of the table. Illuminance levels shall manifest an energy conserving design that indicates coherence to EPA energy efficiency initiatives. For areas not listed in Table 7-4, the recommendations of the 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 7-4: Required Illuminance Levels

Function	Required Illuminance (Footcandles)
General office space – ambient and task lighting	50 (30 ambient + 20 task)*
Animal room	70
Boiler room	20
Corridors	10
Emergency lighting (general, at floor level)	3
Emergency lighting in laboratory blocks, at floor level	5
Laboratory module at work surface (36 inches)	100
AFF (dual switching)	50/100
Loading dock	20
Lobby	20
Locker room	20
Shops (dual switching)	50/100
Record rooms – ambient and task lighting	50
Parking, driveways, and walkways	1 – 3
Stairways	20
Storage, inactive	5
Storage, rough bulky	10
Storage, medium	20
Telephone equipment room	70
Toilets	30
Exterior entrances	5
Desk level (task lighting)	50 – 100
Utility rooms	20
Parking decks	5
Library/conference room (dual switching)	50/100

* Values are at 30 inches above the floor, unless indicated otherwise.

General

Lighting in general office areas, mechanical and electrical equipment rooms, corridors, and similar applications shall be fluorescent or light emitting diode (LED) type. Fluorescent fixtures utilizing linear lamps shall be specified with type T-8 or T-5. Ballasts shall be high-efficiency, Class P, minimum 90 percent power factor. Where available, electronic solid-state ballasts shall be used. Solid-state ballasts shall have a maximum total harmonic distortion of less than 20 percent. All fluorescent lighting shall have tube guards or lens covers; in mechanical areas, fluorescent light fixtures shall have cage guards. Storage areas and mechanical equipment areas with high ceilings shall use fluorescent or high intensity discharge (HID) lamps depending on size of area and height of ceiling. The small size and inherent directionality of white LEDs make them a promising option for a number of general illumination applications such as recessed downlights, undercabinet lighting, desk and task lighting, and outdoor area lighting.

Interior Lighting Control

Switches shall be provided to control lighting in all areas. Provide at least one switch for room lighting at 48 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.

EPA facilities can earn one point toward LEED-ND 2009 certification by providing individual lighting controls for at least 90 percent of the building's occupants and lighting system controls in all shared multi-occupant spaces.

Daylight-Level Sensory Controls

Provide daylight dimming controls in atriums or within 15 feet of windows where daylight can contribute to energy savings. These daylight dimming controls shall regulate control zones of 200 ANSI/BOMA Office Area square feet or less and reduce lighting intensity down to 10 percent.

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 sub zoning of each floor for special functions.

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, and storage rooms. For offices, conference rooms and other non-support rooms, the occupancy sensors shall be manual on/automatic off type. Occupancy sensors shall be located so they have a clear view of the room or area they are monitoring. No more than 1,000 ANSI/BOMA Office Area square feet of open space shall be controlled by an occupancy sensor. All occupancy sensors shall have manual switches to override the lighting control for manual-off only.

Indoor High Intensity Discharge Lighting

In using HID lighting indoors, the required color rendition shall be carefully considered from both visual and health safety perspectives. Where HID fixtures are used for interior illumination, a portion of the fixtures shall be equipped with quartz auxiliary lamp or instant-restrike ballast.

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).

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
- Special purpose characteristics (e.g., vapor-proof, explosion-proof, elimination of radio frequency interferences)
- Total energy consumption
- Total expected lamp life.

For office areas and laboratories, pendant lighting with direct/indirect light is recommended.

Means of Egress Illumination and Markings

The requirements for means of egress are covered in Chapter 9, *Fire Protection*, Section 9.7.2.

Emergency Lighting (Generators and Battery Units)

An emergency lighting system shall be provided in accordance with NFPA 70, Article 700 and arranged to provide a minimum of 3 foot-candles 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 foot-candles of illumination, measured at the exit access door. Where IBC or PBS-P100 emergency lighting requirements also apply, and there is a conflict, use the more stringent standard.

- 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 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.
- Where energy-saving lighting control measures allow egress lighting to be off, the fire alarm shall be able to activate that egress lighting.
- The emergency lighting shall be provided with battery backup and connected to a generator, when a generator is provided.. 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.

- Exit signs shall be of the LED type, have an ENERGY STAR rating, and meet the requirements of NFPA 101.

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/IESNA 90.1 (most recent version), 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.

EPA facilities can earn one point toward LEED-NC 2009 certification for providing interior daylighting in 75 percent or more of all regularly occupied spaces. There are four possible options for achieving this credit, which are detailed in the LEED Reference Guide.

All design of lighting for EPA facilities shall be in accordance with the EPA/DOE ENERGY STAR Program.

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. When 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.

Machine Shops

Fluorescent lights in a machine shop run off the 60 Hz electrical supply and typically strobe at 60 or 120 Hz. This 'stroboscopic effect' causes machines rotating at harmonics of 60 Hz to appear stationary, potentially a safety hazard. Lighting in machines shops must compensate for this stroboscope effect. Some options for providing lighting near rotating machinery include: day lighting, spreading lighting circuits across three phases, lead-lag ballasts, DC lighting, and high-frequency fluorescent luminaires.

Automated 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 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.

Laboratory Fume Hoods

Typically, a two-tube fluorescent light fixture of the longest practical length (up to 4 feet) shall be provided at the top of the laboratory fume hood (LFH). If an alternative lighting design is accepted by EPA, it should be noted on the performance testing documents as to why it is acceptable. It shall provide at least 100 foot-candles of light at the work surface, and shall be designed to accommodate replacement of fluorescent tubes from the exterior of the LFH.

If LFH enclosure panels (e.g., hood-to-ceiling enclosures) are required, access shall be provided to accommodate replacement of fluorescent tubes. The tubes shall be shielded from the hood interior by a tempered glass panel sealed into the LFH body. In LFHs where explosive substances will be used, appropriate explosion-proof light fixtures shall be used. If tubes are provided, they shall be energy efficient (at least T-8) and contain the lowest concentration of mercury that is commercially available.

Use of Incandescent Lighting

Incandescent lighting shall not be used, except by special permission of EPA. Compact fluorescent lamps (CFLs) or LED lights shall be used instead.

EPAct and EISA Requirements

Section 104 of the Energy Policy Act of 2005 (EPAct 2005) requires that, when procuring energy-consuming products, all federal agencies procure either ENERGY STAR or FEMP-designated products. In addition, the Energy Independence and Security Act of 2007 (EISA) requires that incandescent lamps use 25 percent less energy by 2012-2014; the resulting maximum rate wattages and minimum rated lifetimes are displayed in Table 7-5. Light fixtures shall use lamps that meet this standard.

Table 7-5: EISA Standards for General Service Incandescent Lamps

Rated Lumen Ranges	Maximum Rated Wattage	Minimum Rated Lifetime (hours)	Effective Date
1,490 – 2,600	72	1,000	1/1/2012
1,050 – 1,489	53	1,000	1/1/2013
750 – 1,049	43	1,000	1/1/2014
310 – 749	29	1,000	1/1/2014

Source: http://www.energystar.gov/ia/partners/downloads/meetings/DOE_%20ProgramUpdate_Karney.pdf

7.7.2 Fire Safety Requirements for Lighting Fixtures

Lighting fixtures shall comply with NFPA 70 and the following criteria:

- 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 (NFPA 70, Article 410).

- All fluorescent fixtures installed indoors shall be provided with ballasts that have integral thermal overload protection (NFPA 70, Article 410).

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.

Lighting in locations where dangerous gases, liquids, dusts, or fibers may exist shall meet the requirements of NFPA 70, Article 500.

7.7.3 Exterior Lighting

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 BAS, exterior lighting circuits shall be switched by photocells and the BAS, which shall be able to override the photocell switch on request.

EPA facilities can earn one point for reducing light pollution from interior and exterior lighting, There are two possible options for meeting the requirements for interior lighting, which are detailed in the LEED Reference Guide. For the exterior lighting requirements, refer to the call-out box in Section 7.10.1.

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.

LED Lamps

LED lighting offer many advantages compared to HID lighting and technology continues to improve. LED fixtures are more energy efficient, have longer life, are more rugged in use, and have higher lumens per watt. The design should evaluate alternative lighting systems and recommend the best solution for the application.

Parking Lot Lighting

Lighting over driveways and parking areas shall consist of a complete LED 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 one to 3 foot-candles. 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.

Lighting levels for parking lots shall be designed to meet IES standards for “Enhanced Security: under the “Parking Lots” category. Lighting designs shall incorporate an appropriate light loss factor (LLF). The LLF shall not be higher than 0.8. Lighting shall be controlled by photocells, with hand-off-auto switch. Wiring for lighting in large outdoor areas shall use multi-phase branch circuits and adjacent fixtures shall be alternately connected to different phases.
The protective circuit breakers shall be single-phase to preclude a total outage of light in any one area. Pole-mounted lighting fixtures and interior pole wiring shall be protected by in-line fuseholders located within the pole base or transformer housing.

Parking garage lighting is an excellent application for LED lighting for several reasons.

- Most parking garage lights burn 24 hours-a-day – during peak electrical rates.
- The vibration from vehicle traffic creates a harsh environment for traditional light sources.
- Public safety concerns favor white light and a high color rendering index (CRI) and "burned out" bulbs create safety hazards.

Point-By-Point Method

The designers of the lighting system shall provide a point-by-point printout showing the illumination level at all areas of the parking lot. The designers shall require that the lighting equipment vendor submit a similar printout, based on the proposed luminaries, for approval.

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 foot-candles. Entrance ways with cameras shall have an illumination level as required by the security camera to operate.

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.

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 shall be used for roadways.

Exterior Electric Signs

All exterior electric signs shall be integrated into the total design of the facility and approved by the EPA Project Manager.

Site Lighting for Security

An exterior lighting system shall be provided to ensure the security and safety of the occupants and passersby, as well as to support the architectural aesthetic of the building. The properly designed exterior lighting system must provide the minimum required illumination while simultaneously preventing light pollution and light trespass, minimizing glare, and avoiding over lighting. Exterior luminaries must comply with all local zoning laws and lighting levels for exterior spaces must be as indicated by the IES Lighting Handbook.

EPA facilities can earn one point if exterior lighting power densities do not exceed ANSI/ASHRAE/IESNA Standard 90.1-2007 (latest version) for the classified zones and exterior lighting control requirements from ANSI/ASHRAE/IESNA Standard 90.1-2007 (latest version) are met. "Classified zones" (there are four, total) are defined in detail under the Light Pollution Credit in the LEED Reference Guide. The facility must also comply with the interior light pollution reduction requirements (refer to call-out box in Section 7.7.1) to earn this point.

Site lighting is considered any exterior lighting that illuminates the area around the building, defines entrances and exits, or provides traffic flow. Site lighting must adhere to the following guidelines:

- Luminaries selected must have a minimum cutoff of 80 degrees
- Illumination shall be well-controlled and no light can trespass off the building property
- Implement bollards for pathway illumination.

Lighting fixtures at all entrances and exits shall be connected to the emergency lighting system.

7.8 Distributed Power Generation/Renewable Energy

7.8.1 Cogeneration Systems (Combined Heat and Power)

Combined heat and power (CHP) systems combine on-site power generation with the recovery and use of waste heat for making steam, heating or chilling water, or compressing air. They can use a number of technologies to generate power and use recovered heat to drive heating and cooling equipment, such as absorption chillers and desiccant dehumidifiers. These technologies include:

- Turbines
- Microturbines
- Fuel cells
- Reciprocating engines.

For single-building applications, CHP systems make the most sense where electric rates and electric demand charges are high. Sometimes opportunities for CHP can be found when the local utility company is looking to bolster its grid through distributed power production or when there is a need for greater reliability than the utility can provide. The best time to consider CHP for a facility is during the initial planning of new buildings or when major upgrades are planned for HVAC systems. Replacing electric chillers with absorption cooling or engine-driven chillers, for example, presents an excellent opportunity for CHP.

7.8.2 Photovoltaics (Solar Energy Electrical Power Generation Equipment)

Photovoltaic (PV) systems are often cost-effective in small applications removed from utility power. It may costs less to serve a small load with PV than to install a power line, even on a first-cost basis. PV prices have historically declined about 5 percent per year, and PV systems are typically less expensive than operating a stand-alone generator in a remote location. Consider replacing small (less than 10 hp) generators with PV, especially in environmentally sensitive areas where maintenance and fuel spills are a concern. Increasingly, PV is being considered as a source of electrical energy for buildings— even those with ready access to utility power—with the PV

LEED-NC 2009 points are available for EPA facilities that install and operate certain types of on-site renewable energy systems to offset total building energy costs. Eligible renewable energy technologies include solar (thermal and photovoltaic), wind, geothermal (not including ground-source heat pumps), low-impact hydro-power (dams), and biomass or biogas combustion. Refer to the LEED Reference Guide for additional requirements and restrictions.

system integrated into the building envelope.

All PV panels shall be certified by the PowerMark Corporation. Specific types of PV systems in general use are as follows:

Stand-alone Photovoltaic Systems

Stand-alone PV systems can be set up to function in several ways:

- A direct-coupled system is the simplest version and consists of PV cells driving a direct current (DC) load with no battery storage. Loads such as water pumps, ventilation fans, and special DC refrigerators are good applications.
- Battery storage systems to drive DC loads store the PV-produced energy until it is needed—for example, to power navigation aids at night. The simplest version drives DC loads only and requires a battery with charge control to prevent overcharging.
- Battery storage systems to drive AC loads have a charge controller and an inverter (which changes DC to AC) to power connected AC loads. Hybrid systems may have one or more additional energy sources, such as a wind turbine or diesel generator.

Typical stand-alone applications include remote power, emergency communications, irrigation systems for agriculture, microwave repeaters, cathodic protection for bridges and pipelines, navigation aids, security systems, meteorological stations, remote area lighting, and signboard lighting.

Utility-Interactive Photovoltaic Systems

Utility-interactive or grid-connected systems require an interactive inverter to operate with the grid. The PV power is first delivered to the load, and then extra electricity is sent to the grid. The inverter matches the output power to the phase and frequency of the grid. Some considerations are as follows:

- **Net metering**, legislated in a majority of states for residential-scale systems, allows the customer to return excess generated power to their local utility companies at the full retail value, including taxes. The meter turns backward, lowering the customers monthly electric bill.
- **The Public Utilities Regulatory Policy Act** requires utilities to interconnect to any qualified facility. However, the facility must pay for the interconnection.
- **Technical and operating issues** that must be coordinated with the utility are metering, safety, equipment protection, service reliability, and power quality. IEEE standards address interconnection with the utilities; UL standards apply to inverter and PV module performance and safety; NFPA 70 governs wiring issues.
- For situations in which the reliability of grid power is in doubt, the PV system can be designed to automatically replace it during outages.

- When planning a utility-interactive system, be sure to check into metering options, buy and sell rates for power, outdoor disconnect requirements, insurance requirements, and other interconnection costs.

Photovoltaic System Design and Installation

PV system design and installation can be complex. This is particularly true for utility-interactive systems and hybrid systems with supplemental power generation. System designers should be familiar with PV and balance- of-system equipment, as well as all applicable codes and regulatory issues. With Building Integrated Photovoltaic (BIPV) systems, architectural expertise is needed to ensure proper integration with the building and satisfaction of building envelope requirements. Hiring experienced, fully qualified PV system designers is key to satisfactory performance, easy maintenance, and long system life.

Storage Solutions

Storage systems for PV arrays make it possible to use captured energy at night or whenever the PV system cannot meet the load. A typical storage system is a set of batteries sized to accommodate the PV input as well as the load demand. When selecting a battery system, the designer needs to consider:

- Cyclic and calendar life
- Daily depth of discharge
- Temperature and environmental conditions
- Off-gassing characteristics
- Size and weight
- Cost
- Warranty
- Availability
- Reputation of the manufacturer
- Maintenance requirements
- Terminal configuration.

Batteries often contain hazardous materials; the proper use and care of batteries should be a priority throughout their life cycle, including disposal.

7.8.3 Fuel Cells

Fuel cells are cost-effective in situations where very “clean” power (i.e., consistently free of harmonics) and reliable backup energy supplies are essential. Fuels cells generate cleaner power than is generally available from the utility grid, so facilities with equipment that is sensitive to current and voltage variations can use full cells effectively. Remote sites without access to the utility grid are also good candidates for fuel cells. Facilities that can make effective use of waste heat can use that free energy to help offset the devices’ higher cost.

Fuel Cell Technologies

Fuel cells are electrochemical engines that convert the chemical energy of a fuel and an oxidant—hydrogen and oxygen—directly into electricity. The oxygen used in the fuel cell is atmospheric oxygen, and the hydrogen is either elemental hydrogen or hydrogen extracted from hydrocarbon fuels. Water is the only significant byproduct of a fuel cell's operation. The fuel cell's principal components are catalytically activated electrodes for the fuel (anode), the oxidant (cathode), and an electrolyte to conduct ions between the two electrodes. Fuel cells are classified by their electrolyte and the four leading fuel cell technologies are listed below.

Phosphoric Acid Fuel Cells

Phosphoric acid fuel cells (PAFC) have an acid electrolyte and are the most highly developed fuel cells. These operate at relatively low temperatures, around 400°F (200°C), are commercially available, and have thermal output that can be used in cogeneration applications. The Department of Defense (DoD) has been testing 200-kW PAFCs at various facilities since 1993, with generally positive results.

Proton Exchange Membrane

Proton exchange membrane (PEM) fuel cells are well suited to residential, light commercial, and mobile applications requiring relatively compact power systems. The electrochemistry of PEM fuel cells is similar to that of phosphoric acid fuel cells. They operate in the same pressure range but at a much lower temperature, about 175°F (80°C). Their very low thermal and noise signatures may make them especially useful for replacing military generator sets.

Molten Carbonate

Fuel cells using a molten carbonate electrolyte are relatively high-temperature units, operating at higher than 1100°F (600°C). Current molten carbonate fuel cells (MCFC) are being designed for applications on the order of 250 kilowatts (kW) to 5 megawatts (MW). The high-temperature exhaust gases can be used in a combined-cycle (cogeneration) system, creating an overall efficiency of about 80 percent.

Solid Oxide

Solid oxide electrolyte fuel cells (SOFC) are also high temperature devices, operating at 1,100°F to 1800°F. At these temperatures, a natural gas-powered fuel cell does not require a reformer. The solid construction of the SOFC fuel cell prevents some of the corrosion problems of liquid-electrolyte fuel cells. SOFC cogeneration power systems are expected to provide electric power at efficiencies close to 50 percent and useful steam or hot water at about 40 percent of rated power, raising the overall effectiveness of the system. A variety of 20 to 125 kW SOFC units has been tested, and units up to 1 MW are planned for pre-production release.

Fuel cells are inherently less polluting than conventional fossil-fuel technologies and are more efficient in producing electricity. They produce almost no harmful air or water emissions. The principal byproduct is water. However, PAFC, MCFC, and PEM fuel cells have inherent maintenance problems related to water issues.

In comparison, PEM technology, has the best efficiency and power density of all the technologies that run on air at low temperatures. High temperature PVs, such as with the MCFC and the solid oxide fuel cell SOFC, may represent a safety concern, depending on the application.

Size Conditions

The footprint of a 200 kW PAFC unit is about 200 square feet (ft^2), while the footprint of a 2.85-MW MCFC plant is about 4,500 ft^2. For many types of fuel cell power plants, stack and fuel processor units must be replaced every 5 to 10 years, requiring a shutdown of several days.

Assessment

Load characteristics should correspond to distributed generation (DG)/CHP capabilities:

- Peak electrical load and load factor
- Thermal load and load factor
- Thermal storage requirement
- Cost
- Space requirement.

Logistical support:

- **Operations and Maintenance** – understand required capability, commitment, and cost
- **Training** – buyer's technician must attend manufacturer's two-week training program
- **Source of deionized (DI) water** – site must provide for warm water discharge
- **Freeze protection** – heat recovery loop and water supply must be protected
- **Life-cycle cost** – In remote and critical power applications, there are often several options or combinations of options for satisfying peak- and base-load load requirements. For each option, one must evaluate the following cost elements:
    - Annual cost of fuel(s) and delivery thereof
    - Annual cost of maintenance including cell stack renewal
    - Annual value of displaced existing electrical and thermal source energy
    - Amortized costs (equipment, installation, design, administration, commissioning).

7.8.4 Microturbines

Microturbines can produce 25 to 300 kW. They can be used in CHP situations, as a backup generator, and for peak shaving/load balancing. Microturbines shall be UL 2200 listed.

Microturbines should be considered for power generation in the following situations:

- When the reliability of the power supply is extremely important
- When grid-supplied power is limited or very costly (whether from kilowatt hour [kWh] usage, time-of-use, or demand charges)
- When power quality is a concern either because of problems with grid-supplied electricity or because of particular needs for the facility
- When utility companies require DG capacity to meet remote power-user demands
- When thermal energy needs (for heating, absorption cooling, water heating, and industrial processes) can be matched with electricity generation.

From an environmental standpoint, the potential of producing both heat and electricity—i.e., CHP—with microturbines is noteworthy. CHP systems provide an opportunity to dramatically increase the overall efficiency of delivered energy—by 25–30 percent with the microturbine alone to well over 50 percent when waste heat is utilized. Recuperated units have a higher thermal-to-electric ratio than un-recuperated units and can produce 30-40 percent fuel savings, depending on the application.

Advanced materials, such as ceramics and thermal barrier coatings, are key enabling technologies to further improve microturbines. Efficiency gains can be achieved with materials such as ceramics, which allow an increase in engine operating temperature.

7.8.5 Wind Energy Systems

Wind turbines shall conform to the American Wind Energy Association and International Electrotechnical Committee standards.

Small turbines—500 watts to 100 kW—can supply enough electricity to power remote sites, small homes, or business. Large, utility-scale turbines—250 kW and larger—can provide enough electricity to power hundreds of homes and businesses.

Wind energy may be advantageous in the following situations:

- Renewable energy incentives (rebates, tax credits, etc.) are offered
- The power producer can participate in a production tax credit for renewable energy, established under the Tax Relief and Health Care Act of 2006 (H.R. 6111)
- Net metering is available in the state or utility district
- Electricity costs in the area exceed 8 to 12 cents per kWh
- Diesel or other fossil fuels have to be transported to the site for remote power production
- The facility is not in compliance with air pollution regulations
- The facility is attempting to meet clean energy goals.

An annual average wind speed in excess of 8 miles per hour (mph) is required for small-scale systems to be economical, and annual average wind speeds of at least 11.5 to 12.5 mph are required for utility-scale turbines.

Available Power

The power available from wind is proportional to the cube of its speed. At double the wind speed, power generated increases by a factor of eight. Therefore, a wind turbine operating in 11.8 mph wind can generate 29 percent more electricity than one operating in 11.2 mph wind.

Clearances

Wind turbines are available in a variety of sizes and power ratings. A small wind machine has blades between 3 feet and 25 feet in diameter and stands upwards of 30 feet high. The largest machine stands 20 stories high and has blades that span the length of a football field.

Approximately 50 acres of land are required per MW for each utility-scale turbine. However, much of the land is actually unoccupied and can be used for farming, ranching, and other activities.

Although wind turbines generate some noise, a 300 kW turbine creates only 45 dB of noise at a distance of about 650 feet (200 meters). This noise is usually masked completely by background noise or the natural sound of the wind.

7.9 Emergency Power Systems

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, NFPA 101, NFPA 110, and IEEE 446.

7.9.1 Generator Systems

The system shall consist of a central engine generator and a separate distribution system with automatic transfer switch(es), distribution panels, and 480/277 volt lighting panel (if applicable) with dry-type transformers feeding 208/120 volt panels as required. Effort must be made to ensure proper coordination of mechanical engineering elements of the generator systems design.

Service Conditions

If the unit is to be installed outdoors, it shall be provided with a suitable acoustic enclosure and jacket water heaters to ensure reliable starting in cold weather.

When installed at high altitudes or in areas with very high ambient temperatures, the unit must be derated in accordance with manufacturers' recommendations. Operation of starting batteries and battery chargers must also be considered in sizing calculations. In humid locations heaters can reduce moisture collection in the generator windings. Critical silencers are required for all generators.

Acoustical treatment of the generator room shall be provided, if necessary. Temperature and ventilation shall be maintained within the manufacturer's recommendations to assure proper operation of the unit. Calculations to support the size of the intake air supply for combustion, cooling and radiation as well as exhaust piping, and exhaust paths shall be provided by the design engineer.

Radiators shall be unit-mounted if possible. If ventilation is restricted in indoor applications, remote installation is acceptable. Heat recovery and load shedding shall not be considered. Remote location of radiators shall be designed to avoid excess pressure on the piping seals.

A permanently-installed load bank sized at 50 percent of generator rating shall be provided. The load bank shall be factory-mounted to the radiator.

Capacity

The engine generator shall be sized to serve approximately 110 percent of design load; ideally it shall run at 60 percent to 80 percent of its rated capacity after the effect of the inrush current declines. When sizing the generator, consider the inrush current of the motors that are automatically started simultaneously and any UPS systems connected to the generator. The initial voltage drop on generator output due to starting currents of loads must not exceed 15 percent. Day tanks shall be sized for a minimum capacity of 24 hours of generator operation. When using fuel oil as an energy source, provide direct fuel oil supply and fuel oil return piping to the on-site storage tank. Piping shall not be connected into the boiler transfer fuel oil delivery "loop".

Emergency Power Loads

Table 7-6 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 NFPA 70, Article 700.

Table 7-6: Emergency Power Requirements

Emergency System	Acceptable Sources of Emergency Power	
	Building Height** 75 Feet or Less	Building Height** Over 75 Feet
Emergency lighting (1-1/2 hours)	1 or 2, and 3	1 and 3
Means of egress illumination (1-1/2 hours)	1 or 2, and 3	1 and 3
Fire alarm	1 and 3	1 and 3
Fire Pump	NR	1 or 2
Jockey pump	NR	1 or 2
Elevator	NR***	1 or 2*
Smoke control (where required)	1 or 2	1 or 2
Sprinkler system air compressor	NR	NR
Special extinguishing system power supply (dry chemical, CO_2, or other EPA-approved system)	NR	NR
Future hoods (full or partial containment or where deemed necessary)	1 or 2	1 or 2

1 = Generator, 2 = Connection to two separate primary sources or to a utility network system; 3 = Battery with charger

NR – not required; CO_2 – carbon dioxide

* 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 the lowest fire department vehicle access 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.

*** Emergency power (1 or 2) shall be provided for elevators that are part of an accessible means of egress. To be considered part of an accessible means of egress, an elevator must comply with the emergency operation and signaling requirements of section 2.27 of ASME A17.1

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

- Means of egress illumination
- Emergency lighting system—3 foot-candles minimum for egress; 10 foot-candles 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
- Air-conditioning system associated with computer rooms, UPS room, and environmental rooms
- Security systems
- Safety alarm systems.
- Generator auxiliaries
- Visitor screening equipment
- BAS
- Sewage ejector pumps
- Smoke control systems
- High-rise stairway pressurization fans
- UPS' serving technology/server rooms
- Exhaust fan in UPS battery rooms

- Power and lighting for Fire Command Center and Security Control Center
- Federal Aviation Administration (FAA)-required aircraft obstruction warning lights
- Other associated equipment designated by code or by EPA.

Emergency Generator Location

The preferable location for the generator is outdoors. Where possible, the generator should be located with its exhaust as far as possible from (and not directed at) fresh air intakes. The generator should be located away from vibration, acoustic, or electrically sensitive equipment. In addition, 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.

Generator Alarms

Generator alarms must be provided in the generator room. All malfunctions shall be transmitted to the BAS. In all buildings, with or without BAS, a generator alarm annunciator shall be located within the Fire Command Center at the Fire Alarm Control Panel.

Automatic Transfer Switches

Automatic transfer switches serving motor loads shall have in-phase monitors (transfer when normal and emergency voltages are in phase) to reduce possible motor damage caused by out-of-phase transfer. They shall also have pre-transfer contacts to signal time delay returns in the emergency motor control centers. Automatic transfer switches shall include a bypass isolation switch that allows manual bypass of the normal or emergency source to insure continued power to emergency circuits in the event of a switch failure or required maintenance. A closed transition transfer switch will be required where momentary power interruptions are not tolerable.

Fuel Storage Tanks

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 or 72 hours in remote areas. The preferred type of tank is an aboveground storage tank. If allowed by EPA, the tank may be installed underground. Underground tanks shall be of double-wall construction and of non-corrosive material with interstitial monitoring capabilities. The tank shall meet the most recent 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 submittal.

7.9.2 Load Banks

Permanent load banks require approval of the EPA.

7.9.3 Uninterruptible Power Supplies

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 according to the criticality of the area served, with a minimum of 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.

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.

Codes Standards and Documents

The UPS shall be designed in accordance with the applicable codes and standards of the following:

- NFPA 70E Electrical Safety in the Workplace
- NFPA 110 Emergency and Standby Power Systems
- NFPA 111 Standard on Stored Electrical Energy Emergency and Standby Power Systems
- NEMA PE 1 Uninterruptible Power Systems—Specification and Performance Verification
- IEEE 944 Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations
- IEEE 1184 Guide for Batteries for Uninterruptible Power Supply Systems
- ASA-C-39
- Local codes.

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 AC source and it shall in turn supply 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 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.

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.

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 AC source is not available (i.e., operation from battery source only).

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.

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.

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.

UPS Load

The UPS load will consist of the equipment and outlets designated for UPS power connection in the room data sheets.

Battery Room

The battery room for the UPS shall be well ventilated so as not to allow an explosive mixture of hydrogen to accumulate. The battery room shall meet the following requirements:

- ASHRAE and NFPA-111 recommend a minimum of two air changes per hour to remove gases generated by vented batteries during charging or caused by equipment malfunction. Use battery manufacturer's recommendations if more stringent.

- Where mechanical ventilation is installed, the following shall be required
  - Interlock means shall be provided such that initiation of battery charging process will automatically turn on the ventilation fan. A local manual override means shall be provided
  - Airflow sensors shall be installed to initiate an alarm if the ventilation fan becomes inoperative

- Control equipment for the exhaust fan shall be located more than 6 ft from the battery and a minimum of 4 in. below the lowest point of the highest ventilation opening.
- In a dedication battery room all exhaust shall be directly to the outdoors
- Fans shall be spark-resistant, explosion-proof with motors outside the air stream.
- Ductwork shall be a negative pressure system of corrosion-resistant material.
- Exhaust system shall be connected to the emergency power system.

- The supply air shall be approximately 95 percent of the exhaust ventilation rate to maintain slightly negative room pressure to prevent fumes and gases from migrating outside the room. Exhaust air shall not pass over electrical equipment unless the equipment is listed for the use. Supply air inlets shall be no higher than the tops of the battery cells and exhaust outlets at the highest level in the room.

- Acoustical enclosures shall be provided to maintain a maximum NC level of 35.

- Emergency eyewash station shall be provided.

- Emergency shower and floor drain shall be provided.

- Other mechanical requirements as indicated in Chapter 6.

The installation of the UPS system shall be in accordance with NFPA 111.

Explosion-proof wiring methods 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 is necessary in order to prevent classification of the battery room as a hazardous (classified) location, in accordance with NFPA 70, 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.

7.10 Communication Systems

7.10.1 Telecommunications Distribution and Equipment.

Sufficient space shall be provided on the floor(s) where the EPA occupies space for the purposes of terminating telecommunications service into the building. The building’s telecommunications closets located on all floors shall be vertically-stacked and connected to the server/network room via 4-inch conduits (empty sleeves). Telecommunications switchrooms, wire closets, and related spaces shall be enclosed. The enclosure shall not be used for storage or other purposes and shall have door(s) fitted with an automatic door-closer and card reader controlled electric strike.

Telecommunications switch rooms, wire closets, and related spaces shall meet applicable Telecommunications Industry Association (TIA) and Electronic Industries Alliance (EIA) standards. These standards include the following:

- TIA/EIA-568, *Commercial Building Telecommunications Cabling Standard*

- TIA/EIA 569, *Commercial Building Standard for Telecommunications Pathways and Spaces*

- TIA/EIA-570, *Residential and Light Commercial Telecommunications Wiring Standard*

- TIA/EIA-607, *Commercial Building Grounding and Bonding Requirements for Telecommunications Standard*.

Telecommunications switch rooms, wire closets, and related spaces shall meet applicable NFPA standards. Bonding and grounding shall be in accordance with NFPA70 and other applicable NFPA standards and/or local code requirements.

If offsets are required between any two telecommunications closets, provide a suitable system of conduit, pull boxes, and/or cable tray to accommodate riser cables.

Each telecommunications closet shall accommodate vertical and horizontal cable terminations, patching, Local Area Network (LAN) hubs, switches, and similar equipment. No security, building management system, fire alarm, other base building panels, cables, equipment, water pipes or plumbing fixtures shall be housed in the telecommunications closets, except where fire alarm detection and fire sprinkler protection is provided for room protection.

Provide each telecommunications closet with 24/7 HVAC and normal, UPS, and emergency generator power for technical loads. Dedicated electrical panels shall be provided in each closet.

Telecommunications closets should not be located directly adjacent to electrical switchgear, transformers, mechanical equipment rooms, large pumps, or other potential sources of electromagnetic interference.

Telecommunications closets should not be located adjacent to stairways, janitor closets, toilet rooms, mechanical rooms, electrical closets, elevator shafts, or other elements that would preclude access to, and cable distribution from, the closets. Door should swing outward if it does not interfere with building egress.

The telecommunications closets shall be a minimum of 100 ft^2 in size, with 36-inch wide solid core doors secured with key locks or card access.

All telecommunications circuits must come from at least two separate, diverse points of entrance into the building. Routing of all incoming circuits should be from non-duplicated cable sources.

Each point of entrance for telecommunications circuits used by EPA must be enclosed inside a dedicated slab-to-slab concrete room that has a steel door with hidden hinges and double locks. This room cannot be shared by any other building tenants.

7.10.2 Telecommunications/Data Systems

One telephone outlet and one LAN computer shall be provided per 125 net usable ft^2 (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 EPA 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.

7.10.3 Video Conferencing 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-dB loss specifications of the technical advisory manuscript concerning the wiring.

7.10.4 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 (omni-directional) to recorders for a complete system.

7.10.5 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.

7.10.6 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.

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.

7.10.7 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.

7.10.8 Telecommunications Room

The telecommunications room must be located in a secure area of the building. The room shall not be located adjacent to either the telephone equipment room or main computer. The room shall not be located:

- Within 25 feet of an outside wall or delivery area
- Beneath laboratories, kitchens, laundries, toilets, showers, and other areas where water service is provided.

7.10.9 Other

A complete raceway system shall be furnished for other communication/data systems. 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.

7.11 Fire Alarm System

Refer to Section 9.2 for a description of the fire alarm system requirements.

7.12 Safety Alarm System

7.12.1 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.

7.12.2 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 status:

- 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 EPA on a case-by-case basis.

7.13 Security Systems

7.13.1 Security Control Centers and Building Management Systems

The Security Control Center (SCC) and Operational Control Center (OCC) may be co-located. If co-located, the chain of command should be carefully pre-planned to ensure the most qualified leadership is in control for specific types of events. Secure information links between the SCC, OCC, and Fire Command Center shall be provided. A backup control workstation should be provided in a different location, such as a manager's or engineer's office. If feasible, an off-site location should be considered. As an alternative, a fully redundant Backup Control Center can be installed. 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.

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.

7.13.2 Access Systems

A complete building access system shall be designed as an on-line type that reports to a central controller. The professional that is designing this system shall have at least three years of experience in the design of similar installations.

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 ft^2 of gross floor area (in addition to the vestibules) and at entry to controlled computer areas.

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.

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.

Programmable Key Pad (Small Facilities)

For 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.

7.13.3 Intrusion Detection Systems

A design professional with a minimum of three years experience in the design of similar installations shall design a complete intrusion detection system. The intrusion detection system shall provide protection based on the site-specific security levels detailed in the ISC Physical Security Criteria for Federal Facilities, April 2010. Security criteria are listed below in Table 7-7.

Table 7-7: IDS Protection Criteria

Security Criterion	**Level I – Minimum**	**Level II – Low**	**Level III – Medium**	**Level IV – High**	**Level V – Very High**
Intrusion Detection System (IDS) Coverage	No special measures required	Provide IDS on perimeter entry and exit doors, and operable ground-floor windows.	Provide IDS on perimeter entry and exit doors, and all ground-floor windows.	Provide IDS on perimeter entry and exit doors, and all windows within 16 feet of the ground or other access point.	Provide IDS on perimeter entry and exit doors, and all windows within 16 feet of the ground or other access point, and any other openings larger than 96 square inches.
Intrusion Detection System (IDS) Monitoring	Install local annunciation if IDS is in use.	Monitor at a central station with notification to a building manager or designated tenant POC.	Monitor at a central station (on or offsite) with notification to law enforcement or security responders.	Monitor at an on-site central station during operating hours, with response by law enforcement or security responders.	Monitor at an on-site central station with response by on-site guard force.

. 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. ISC Physical Security Criteria for Federal Facilities lists the following acceptable IDS access control options for door switches: balances magnetic switch, passive infrared sensor, alarm system keypad, or alarm system panel. Each door switch must also have an individual tamper sensor. EPA designates that all door switches shall be of the balanced magnetic type.

The entire system shall be monitored at the central control desk of the facility and locally recorded to monitor as evidentiary data if necessary. Depending on site-specific characteristics and security levels, the system may be remotely monitored either on the campus, by an alarm company, by the local law enforcement agency, or by another agency or monitoring group if the facility is in a leased space.

7.13.4 Duress Alarms

Call buttons should be provided at key public contact areas and as needed in the offices of managers and directors, in garages, and other areas that are identified as high risk locations by the project-specific risk assessment. Duress alarms shall be provided based on the site-specific security levels detailed in the ISC Physical Security Criteria for Federal Facilities, April 2010. Security criteria are listed below in Table 7-8.

Table 7-8: Duress Alarm Specifications

Security Criterion	Level I – Minimum	Level II – Low	Level III – Medium	Level IV – High	Level V – Very High
Duress Alarms or Assistance Stations	Implement duress procedures for emergency situations.	Implement duress procedures for emergency situations.	Provide duress button or call buttons at guard posts and sensitive public contact areas.	Provide duress button or call buttons at guard posts, sensitive public contact areas, in garages, and other ares that are identifies as high-risk locations.	Provide duress button or call buttons at guard posts, sensitive public contact areas, in garages, and other ares that are identifies as high-risk locations.

7.13.5 Site Access Systems

One alarm zone with a multi-beam pair of IR columns or CCTV with video analytics shall be provided to monitor vehicles passing through the each gate of a fenced area. The camera/IR columns should be positioned to monitor the entire length of the fence on the side with the gate and alarm metadata tied to the video head end to activate full-frame CCTV recording of the event for a period of time (typically between 15 and 30 seconds) before and after the alarm. For facilities that require enhanced security due to site-specific conditions and/or assessments, a multi-beam infrared column can be used to monitor the gate and fenced area in conjunction with video analytics to provide redundant system alarms. The alarm zone shall be remotely monitored at the central alarm desk.

7.13.6 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 three 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.

Cameras, Fixed or Pan-Tilt-Zoom

RECOMMENDED MINIMUM CAMERA SPECIFICATIONS

Common:

1. NTSC video format
2. Variable frame rate: 5ips – 30ips (images per second)
3. Vandal resistant, environmental housings as required by the manufacturer to meet climate conditions.
4. 4 CIF resolution
5. IP-based output (preferred) or analog output IP-encoded at the source (in hybrid systems that utilize existing cameras)

Fixed Camera (Open, Enclosed, Dome, or Pendent):

1. Video capture chip: 1/3" CCD or CMOS
2. Day/Night capability
3. Minimum light requirement:
    a. Color: 0.2 lux (non-augmented)
    b. B/W: 0.1 lux (non-augmented)
4. Optical zoom (non-augmented): 3x
5. Manual vari-focal lens
6. Infra Red-corrected lens
7. Auto-iris
8. Wide dynamic range
9. Power: 12v, 24v, Power-Over-Ethernet (POE) capable
10. IP Protocols: IPv4/v6
11. Compression: JPEG (still images), MPEG-4 (motion video, H.263 is acceptable but H.264 is preferable)
12. F-stop (or ISO equivalent): F1.4
13. Additional items from individual manufacturers to assess the value added. Some preferred examples would be: digital zoom, augmented light sensitivity (ie. Bosch SenseUp, Sony XDNR), signal to noise ratio > 32db (20 log rule)

Pan-Tilt-Zoom (PTZ) Camera:

1. Video capture chip: 1/4" CCD or CMOS
2. Day/Night capability
3. Minimum light requirement:
    a. Color: 1 lux

   b. B/W: 0.3 lux
4. Optical zoom (non-augmented): 26x
5. Automatic vari-focal lens
6. Infra Red-corrected lens
7. Auto-iris
8. Wide dynamic range
9. Power: 12v, 24v, Power-Over-Ethernet (POE) capable
10. IP Protocols: IPv4/v6
11. Compression: JPEG (still images), MPEG-4 (motion video, H.263 is acceptable but H.264 is preferable)
12. Auto-pivot picture
13. Additional items from individual manufacturers to assess the value added. Some preferred examples would be: digital zoom, augmented light sensitivity (ie. Bosch SenseUp, Sony XDNR), signal to noise ratio > 32db (20 log rule)

Long Distance Fixed Camera (IR Imager):

At present, only one manufacturer has been able to achieve the specifications listed below (Bosch ZX55-IP IR Imager). However, should another manufacturer achieve these specifications, they shall be used as a minimum level of performance. Detection – 1000’, Recognition – 500’, Identification – 330’

1. Video capture chip: 1/3” CCD
2. Day/Night capability
3. Minimum light requirement:
   a. Color: 0.02 lux
   b. B/W: 0.0 lux, total darkness
4. Optical zoom (non-augmented): 10x, 9mm – 90mm
5. Automatic vari-focal lens
6. Infra Red-corrected lens
7. Auto-iris
8. Wide dynamic range
9. Power: 12v, 24v
10. IP Protocols: IPv4/v6
11. Compression: JPEG (still images), MPEG-4 (motion video, H.263 is acceptable but H.264 is preferable)
12. Built-in 940nm IR-illuminator (Black Diamond UFLED) with metallic diffuser

Infra-Red (IR) Illuminators:

IR illuminators are used when visible lighting to augment camera light sensitivity is not feasible or desired. IR illuminators can reduce bandwidth required for video transmissions and subsequently reduce the storage space requirements. The human eye generally detects visible light wavelengths between 390nm and 750nm. IR-corrected camera lenses should be utilized wherever possible. IR-illuminators should match the wavelength of the IR-corrected lens as closely as possible to achieve maximum possible video quality as defined by ITU-T J.246 and J.247 as well as the maximum possible distance achievable by the combined equipment. IR-illuminators must be focused on the center of the desired video image and provide diffuse even lighting.

1. Power: 12v, 24v
2. EM wavelength: 850nm and 940nm (matched to IR-corrected lens)

Beam pattern: Horizontal and vertical beam patterns vary between manufacturers but are expected to envelop the primary target of the video captured.

Cameras, Monitored and Controlled

All cameras shall record activities for evidentiary purposes at the facility's central control station. Some cameras shall also 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 (shall be provided immediately next to all CCTV camera locations with environmental enclosures equipped with wiper, puffer, heater or blower systems. Alternatively and secondary power distribution block may be provided for environmental enclosures via the head-end.

RECOMMENDED MINIMUM RECORDING REQUIREMENTS

1. Available video channels to be 10% or four greater than the number of cameras required for the design, whichever is greater.
2. 540p TV lines (NTSC). HD resolution, >720p is acceptable but must have a compelling need per Amtrak Police Department (APD) - Corporate Security.
3. Up to 16 alarm monitoring points per recorder.
4. Remote (browser-based) client connectivity up to 200 servers.
5. Emergency agent and Email notification on alarm.
6. PIP for live and playback of video.
7. Geolocation metadata capable.
8. Searchable timeline.
9. Local and remote PTZ control with Third-Party PTZ controls (both joystick and software-based).
10. Support partitioned, external RAID-10 or RAID-5 storage with 20% additional capacity based on storage calculations.
11. Optional wall and rack mountable components.
12. Self-initiated system diagnostics.
13. All video recording digitally watermarked.
14. Video playback via integrated player (no log-out/log-in required).
15. Video playback format MPEG-4.
16. Video image and metadata PUSH to mobile devices (ex: iPhone, PDA, Blackberry, Android).
17. Uninterrupted Power Supply (UPS): 15 minutes when a secondary power source (generator) is available, 4 hours when a secondary power source is not available.

Closed-Circuit Television Security Cameras, Loading Docks

CCTV cameras shall be provided to monitor entry and exit from the loading dock areas. CCTV cameras should be positioned and angled to allow monitors to capture views of both vehicles and personnel on loading dock platforms. 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.

7.13.7 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.

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.

7.13.8 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.

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). The door shall be monitored at the central control station in case it is left open or the card access system is bypassed.

7.13.9 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.

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).

7.14 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.

8. BUILDING AUTOMATION SYSTEMS

A building automation system (BAS) is a computerized, intelligent network of electronic devices, designed to monitor and control the mechanical and lighting systems in a building. The BAS core functionality:

- Keeps the building climate within a specified range
- Provides lighting based on an occupancy schedule
- Monitors system performance and device failures and provides email and/or text notifications to building engineering staff.

The BAS typically reduces building energy- and maintenance-related costs compared to a non-controlled building.

LEED-NC 2009 strongly encourages facilites to maximize their energy performance (at least 10 and as many as 19 points are available under Credit EA 1). Experience at existing EPA and other Federal facilities has clearly demonstrated that a sophisticated building automation system, including a comprehensive energy management system and direct digital control (DDC) network is essential for maximizing energy efficiency and energy performance. The basic requirements for the BAS are contained in this chapter.

No control system, however well designed, can correct for inadequate source equipment, poorly selected components, or mismatched systems. Energy efficiency requires a design that is optimized through:

- Realistic prediction of loads
- Careful selection of equipment and systems
- Harmonization of new and existing systems with the BAS control and data collection functions.

An integrative design process shall be followed, encompassing mechanical engineering, electrical engineering, control systems engineering, and other applicable design professions to maximize performance and value of the BAS and related control systems.

A BAS will be required for all new facilities or major renovations of existing facilities for which the entire facility space is greater than 100,000 square feet (ft^2). Smaller projects shall be evaluated on a case-by-case basis to determine the need for, or suitability of, a BAS. The following factors shall all be considered in the decision to specify and install a BAS:

- Size of the building
- Number of pieces of equipment
- Complexity of equipment and systems
- Potential magnitude of energy savings
- Availability of properly trained and experienced personnel.

It is expected that the BAS at newer facilities or those that have undergone major renovations will reflect a high degree of intelligent building functions including:

- Data retrieval, storage, and manipulation
- Self-diagnostic capabilities
- Three-dimensional building information modeling capabilities.

The BAS must be commissioned upon startup of a new facility or major renovation to an existing facility. Commissioning the BAS is one of the most integral (and intricate) aspects of commissioning, in order to ensure that the entire building functions as a properly integrated system. Guidelines for commissioning are contained in Chapter 1, Section 1.8 and Appendix E of this Manual.

8.1 Direct Digital Control Network

The BAS shall be an interconnected network of direct digital control (DDC) systems supervised by a central computer and accessible via a Web browser. The BAS shall possess a fully modular architecture, permitting expansion through the addition of stand-alone control units, modular building controllers, unitary controllers, digital point units, multiple point units, terminal equipment controllers, operator terminals, and control computer(s) (*refer to Section 8.1.1 for computer specifications*). DDC signals shall be arranged to precisely sequence heating valves, dampers, and cooling valves without overlap. Unless otherwise specified, sequenced devices will have a separate DDC output for each device (spring range sequencing will not be permitted). In addition, each start/stop function shall be controlled from a separate DDC output. DDC controllers shall be electronic (unless pneumatic controls would provide greater energy efficiency and/or speed of response).

Standard control functions that use open-loop logic (i.e., without feedback to related systems and indirect control logic) are inappropriate in BAS control sequences, which instead require closed-loop control logic to assure feedback to related systems. Comprehensive sequencing of controls provides facility managers the greatest comfort possible at the lowest possible energy consumption, by taking advantage of diversity and precisely coordinated system interactions.

The BAS shall utilize “open” communication protocols such as Building Automation and Control Networks (BACnet), LonWorks™, or equivalent, to minimize the costs of providing integration and allow interoperability between building systems and control vendors. Other open protocol language systems, such as LonTalk™, may also be used provided there is compatibility with overall regional and/or central monitoring and control systems and strategies. The BAS shall include energy management and monitoring software. The BAS shall have a graphical user interface (GUI) (*refer to Section 8.1.2*) and offer the following features:

- Trending
- Scheduling
- Capability to download memory to field devices
- Real-time, “live” graphics programs
- Parameter changes of properties
- Set point adjustments
- Alarm/event information

- Confirmation of operators
- Execution of global commands.

Table 8-1 contains guidelines for DDC systems, which may be modified depending on project-specific requirements.

Table 8-1: Guidelines for DDC Systems

Control Parameter	Range of Control	Sensitivity	Display
Space Temperature	50°F – 85°F	± 1.0°F	Nearest 0.5°F
Duct Temperature	30°F – 130°F	± 1.0°F	Nearest 0.5°F
Heated or Chilled Water Temperature	40°F – 280°F	± 1.0°F	Nearest 0.5°F
Duct or Building Static Pressure	Design-Specific	± 25% of Range	Nearest 0.01 in WC
Space Relative Humidity	10% – 90%	± 3%	Nearest 1%
Duct Humidity	0% – 100%	± 5%	Nearest 1%

°F – degrees Fahrenheit; in WC – inches of water column

A BAS requires measurements at key points in the building system to monitor part-load operation and adjust system set points to match system capacity to load demand. Tables 8-2 and 8-3 list the minimum control points and monitoring parameters for typical heating, ventilation, air conditioning, and refrigeration (HVAC) systems and equipment.

Table 8-2: Minimum Control Points for HVAC Systems

System Component	Control Points	Alarms
AHUs and Terminal Boxes (Constant Volume and VAV)	• Start/stop supply and exhaust fans • Heating control • Cooling control • Humidification control • Supply air volume reset • Adjustable supply air volume (VAV) • Static pressure reset • Zone temperature reset (each zone) • Zone pressurization control (each building zone) • Damper position (economizer) • Enable/disable economizer cycle • Carbon dioxide (CO_2) concentration • Terminal unit damper position • Space pressure or CFM offset (laboratory spaces)	• Fan failure • Zone space temperature rise of 5°F above set point • Zone relative humidity of 5% below set point • Freeze-stat activation • High and low static pressure cut-outs • High humidity limit • Space pressure above or below offsets • CFM above or below offsets

Table 8-2: Minimum Control Points for HVAC Systems

System Component	Control Points	Alarms
Chillers	• Start/stop • Leaving water temperature reset • Isolation valve position	• Failure • Chilled water temperature rise of 5°F above set point • Chilled water pump failure • Release of refrigerant
Hot Water Boilers	• Start/stop • Leaving water temperature reset • Isolation valve position	• Hot water decrease of 5°F below set point • Hot water pump failure • Common boiler failure point
Cooling Towers	• Start/stop • Leaving water temperature reset • Isolation valve position • Fan speed	• Fan failure • Backside cooling loop pump failure • Basin heater cutout
Pumps	• Start/stop • Differential pressure reset	• Pump failure
Other	NA	• Water on floor of Mechanical Room • Laboratory fume hood sash position and hood alarm condition

AHU – air handling unit; VAV – variable air volume; °F – degrees Fahrenheit; NA – not applicable

Table 8-3: Minimum Monitoring Parameters for HVAC Systems

System Component	Monitoring Parameters
AHUs and Terminal Boxes (Constant Volume and VAV)	• Supply air temperature • Return air temperature • Mixed air temperature • Leaving chilled water temperature • Entering chilled water temperature • Leaving hot water temperature • Entering hot water temperature • Temperature and humidity in each zone • Fan speed • Differential pressure across filter(s) • Supply air flow rate • Exhaust air flow rate • Outside air intake flow rate (AHUs) • Room or zone CO_2 concentration • Damper position • CFM offset (laboratories and vivaria)
Chillers	• Leaving water temperature • Entering water temperature • kW draw • Leaving water flow rate
Hot Water Boilers	• Leaving water temperature • Entering water temperature • Leaving water flow rate • BTU draw
Steam Boilers	• Leaving water temperature • Entering water temperature • Leaving water flow rate • BTU draw • Flue gas temperatures • Steam pressure
Cooling Towers	• Entering water temperature (from condenser) • Leaving water temperature (to condenser) • Backside cooling loop water temperature (in) • Backside cooling loop water temperature (out) • Fan speed • Basin heater temperature
Pumps	• Differential pressure • Liquid flow rate
Utilities	• Natural gas consumption • Electricity consumption • Electricity demand • Makeup water consumption

Table 8-3: Minimum Monitoring Parameters for HVAC Systems

System Component	Monitoring Parameters
	• Fuel oil consumption • District-supplied hot water • District-supplied chiller water • District-supplied steam temperature and pressure
Fume Hoods (laboratories) and Ductwork	• Fan start/stop • Static and dynamic pressure • Volumetric flow rate (cfm) • Fume hood face velocity • Fume hood sash position

AHU – air handling unit; VAV – variable air volume; CO_2 – carbon dioxide; kW – kilowatts; BTU – British Thermal Unit; cfm – cubic feet per minute

The system shall be capable of logging all data listed above or a subset of these parameters selected by building operators. In all new buildings and major renovations, the BAS shall have at least 20 percent spare capacity for future expansion. The system must provide for stand-alone operation of subordinate components. The primary operator workstation(s) shall have a graphical GUI. Stand-alone control panels and terminal unit controllers shall have hand-held or fixed, text-based user interface panels.

8.1.1 Control Computer Hardware Requirements

Control computer hardware shall consist of, at a minimum, one portable (laptop) workstation/tester and one central workstation/tester. All hardware shall have the capabilities to:

- 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 or digital output
- Provide an operator interface, contingent on password level, allowing the operator to use full English language words and acronyms, or an object-oriented GUI
- Display and 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 American National Standards Institute/Electronic Industries Alliance/Telecommunications Industry Association [ANSI/EIA/TIA] 232-F port)
- Disable and enable each DDC.

8.1.2 Person-Machine Interface Software

The BAS person-machine interface (PMI) software is the major influence in complex situations such as the handling of trouble calls and alarms reported by the BAS. These calls are a complicated mix of:

- The type of call/alarm
- The criticality of the alarm
- The individual(s) required to respond
- The time of day
- The troubleshooting ability of the respondent.

The comfort level that the respondent to the call feels toward the PMI is the major variable in the response to alarms and trouble calls. "User friendly" features to consider for the PMI include:

- GUI
- Schematic and "picture" representations
- “Help” features
- Screen function and prioritization
- Software main menu structure
- Multiple levels of jurisdictions and clearances
- Method to standardize point descriptions and formats
- Scheduling, programming, and reporting features.

All required software to operate the BAS (including all DDC functions) shall be furnished as part of the complete DDC system. Updates to the software shall be provided upon commercial release and incorporated into operation and maintenance (O&M) manuals, as part of the required technical support for the software products.

8.1.3 Wireless Sensor Technology

Installation of wireless sensor technology should be considered for control, metering, and monitoring devices. The primary components of a wireless sensor data acquisition system include:

- Sensors
- Signal conditioners
- Transmitters
- Repeaters (optional)

- At least one receiver
- Computer (if data processing is planned)
- Connections for external communications to users (e.g., building operators).

Table 8-4 lists common wireless sensor types and the applications for which they shall be considered.

Table 8-4: Wireless Sensor Types and Applications

Frequency Band (MHz)	Topology and Communications	Applications	Power Source
900	Point-to-multipoint; serial-FHSS	• Building temperature sensing • Electric power metering • Building security	• Temperature sensors—battery powered • Receivers—line powered with 24 VAC power supply • Repeaters—line powered with battery backup
	Point-to-point and point-to-multipoint; serial	• Remote monitoring with long-distance communication • Building to building communication • Remote facility monitoring	• 11 VDC – 25 VDC from power supply connected to line power
2,400	Point-to-point; serial	• Temperature, humidity, and other parameter monitoring	• 10 VDC – 30 VDC from power supply connected to line power
900 and 2,400	Mesh network	• Temperature, humidity, occupancy, and other building parameters	• Battery- or line-powered
Cellular Network Bands	Point-to-point and point-to-Internet	• Monitoring of electrical power use and other critical parameters	• Battery- or line-powered

Acronyms: VAC – volts, alternating current; VDC – volts, direct current; FHSS – frequency-hopping spread spectrum; MHz - Megahertz

Factors that should be considered in deciding when to use wireless sensing in facilities (and what type of wireless sensing devices) include the following:

- Need for, and availability of, integration components or gateways to connect wireless sensor networks to the BAS, other local area networks, and/or the Internet
- Availability of battery-powered wireless devices
- Battery life
- Frequency of data collection and its relationship to battery life (where applicable)
- Battery backup for line-powered devices

- Proper packaging and technical specifications for the environment where devices will be located
- Availability of software for viewing and processing the data for the intended purpose
- Compatibility among products from different vendors and adherence to common protocols (e.g., Institute of Electrical and Electronics Engineers [IEEE] 802.15.4, ZigBee)
- Tools for configuring, commissioning, repairing, and adding nodes to the sensor network
- Software to monitor network performance
- Availability of technical support
- First (capital) costs
- Life cycle costs.

8.1.4 Design Considerations

The design submittal shall include complete control system drawings, complete technical specifications, and sample commissioning procedures for each control system that is in turn a component of the BAS. The control logic, once in place, dictates the efficacy of the BAS. Potential opportunities for optimization of the system include, but are not limited to:

- Device/system start/stops
- Temperature resets
- Temperature setbacks
- Operation schedules
- Control loop tuning.

On a case-by-case basis, for major renovations, the best alternative may be complete replacement of the existing BAS or facility-wide control system, as opposed to partial installation and integration with the existing system. The controls engineer shall conduct a life cycle cost evaluation of both alternatives to aid in decision-making. Projected energy savings from enhanced controllability and lighting controls shall be factored into the life cycle cost evaluation along with relevant computer hardware and software costs.

8.1.4.1 Laboratories

BAS control requirements for unique and diverse laboratory environments have additional considerations and requirements. To the greatest extent possible, all laboratory space shall be designed consistent with the most recent guidance provided by the U.S. Environmental Protection Agency's (EPA's) and U.S. Department of Energy's (DOE's) joint Laboratories for the 21st Century (Labs21®) program.

Proper location of sensors is critical in a laboratory environment, in order to avoid potential performance deficiencies, malfunction, or damage. For example, temperature sensors can usually be installed in locations where chemicals are used and/or surfaces are routinely sanitized.

In contrast, humidity sensors can be very sensitive to chemicals and also must be protected from normal sanitizing procedures.

Laboratory ventilation shall be monitored either directly with flow sensors or indirectly with pressure differential sensors in ductwork or between adjacent areas. Fan motors shall be equipped with current monitors and alarms that indicate impending failure of the motor. Humidification monitoring can be provided within the duct system or in various areas of the laboratory where humidity ratio is critical. In order to ensure isolation of laboratory operations (and potential hazards thereof), sensors shall be installed to monitor the differential pressure between the laboratory space and the support space.

Certain laboratory operations may require cooling water on a routine and/or emergency basis. In those situations, appropriate sensors and controls shall be installed to enable delivery of cooling water, as required.

Animal room environmental conditions (e.g., temperature, humidity, ventilation airflow) must be monitored consistent with applicable safety and animal welfare standards. Environmental monitoring systems in animal rooms should be combined with automatic watering, through-flush, and access control system packages, where feasible.

8.2 Level of Integration

The BAS should be designed and installed to provide master control over all building systems and functions. Based on project requirements, the EPA project manager may require that one or more of the following systems be operated by control panels and networks that are independent from the BAS:

- Lighting
- Fire alarms
- Security
- Elevators.

8.3 Automatic Controls

Pre-programmed and stand-alone single or multiple loop microprocessor proportional integrative derivative controllers shall be used to control all HVAC and plumbing subsystems.

8.3.1 Temperature Controls

All chillers, boilers, terminal boxes, and air handling units (AHUs) shall have self-contained BACnet or LonWorks controllers (or equivalent) that are capable of communicating with the BAS. Heating and cooling energy in each zone shall be controlled by a thermostat or temperature sensor located in that zone. Independent perimeter systems must have at least one thermostat or temperature sensor for each perimeter zone.

Temperature inputs shall be a signal from resistance temperature detector (RTD) elements or precision thermistors, depending on cost and the accuracy required by the application. Temperature sensors using RTDs should include platinum elements. In systems and applications with high time constants (e.g., large rooms and laboratories), temperature sensors shall be thermistors as opposed to RTDs.

A 5-degree Fahrenheit (5°F) dead band shall be used between independent heating and cooling operations within the same zone. Simultaneous heating and cooling (i.e., conditioning the space by reheating or re-cooling supply air or by concurrently operating independent heating and cooling systems serving a common zone) shall not be used except under the following conditions:

- Renewable energy sources are used to control temperature and/or humidity
- Project-specific temperature, humidity or ventilation conditions require simultaneous heating and cooling to prevent space relative humidity from risk above space-specific or facility-specific requirements (e.g., specialized laboratory spaces)
- Project-specific building construction constraints prohibit installation of other types of HVAC systems (EPA must review and provide pre-approval).

Night set-back and set-up controls must be provided for all comfort conditioned spaces, even if initial building occupancy plans are for 24-hour operation. Morning warm-up or cool-down, as applicable, must be part of the control system. Controls for the various operating conditions must include maintaining building-specific pressurization requirements (e.g., negative pressurization of laboratory spaces). An occupancy override “ON” control must be made available for occupants via the thermostats or as scheduled through the building operator.

8.3.2 Humidity Controls

Summer and winter space or zone humidity control shall be provided only on a space-by-space or zone-by-zone basis. Unless dictated by project-specific requirements, relative humidity shall be maintained between 30 percent and 65 percent, as dictated by American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) 62.1. In addition, 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.

Indoor and outdoor humidity sensors shall be calibrated in place during system startup and at least annually thereafter. Dew point control is preferred because it tends to ensure more stable humidity levels. However, relative humidity sensors are acceptable, provided they have been calibrated in place and that they are co-located with dry bulb sensors (i.e., such that the BAS can convert the two signals to a dew point value for control purposes).

8.3.3 Ventilation Controls

All supply, return, and exhaust ventilation systems shall be equipped with automatic and manual controls that enable shutdown of fans 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 necessary to meet ventilation requirements (ASHRAE 62.1 or project-specific criteria) is being introduced into the system. Unless otherwise required by life safety or the specific project criteria, automatic dampers shall fail open for return air and fail to a minimum setting to outside air.

EPA facilities can earn one LEED-NC 2009 point for maintaining outdoor air ventilation rates to occupied spaces at least 30 percent above the minimum rates required by ASHRAE Standard 62.1 (latest version) (calculated in the breathing zone).

Unless otherwise specified based on project requirements, automatic air control dampers must meet the “low leakage” criteria contained in the Air Movement and Control Association’s Publication 500-D-2007, *Laboratory Methods of Testing Dampers for Rating*—maximum leakage of 6 cubic feet per minute [fpm] per ft^2 at a maximum system velocity of 1,500 fpm and a 1-inch pressure differential). The dampers shall be opposed-blade type for modulating control, but may be opposed-blade or parallel-blade type for two-position control. Pilot positioners and operators shall be located outside of the air stream.

The BAS must allow complete monitoring, control, and set point adjustment of all points and variable air volume (VAV) terminal unit controllers. Outside air quantity to each AHU shall be automatically controlled to meet the requirements of ASHRAE 62.1-2007, *Ventilation for Acceptable Indoor Air Quality* (refer to Chapter 6 for an overview of the requirements in ASHRAE 62.1-2007).

- VAV systems shall be designed with sensors and feedback control devices that sense ductwork static air pressure and velocity pressure, and that control supply fan airflow and static pressure output by modulating the input frequencies on the VFD motors (ASHRAE 62.1-2007).

These control systems shall have a minimum of one static pressure sensor mounted in the ductwork downstream from the fan(s) and one static pressure controller to vary fan output by adjusting the frequency inputs to the VFD motors and fan drives.. Exhaust fans, supply fans, and return or relief fans shall have devices that control fan operation such that:

- Air volume output of the fan(s) is continuously monitored; and
- Supply air volume to the space constantly meets, or has the capability to exceed, the fixed minimum outdoor air ventilation requirements.

8.3.4 Fire and Smoke Detection and Protection Controls

All air handling systems shall be provided with smoke and fire protection alarms and controls, in accordance with:

- NFPA 72 -2007
- NFPA 90A
- NFPA 101
- International Building Code (IBC)
- GSA PBS P-100
- Applicable state and local building codes

Per NFPA 90A, smoke detectors are not required for fan units whose sole function is to remove air from the inside of the building to the outside of the building. 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, as required by NFPA 90A.

Special exhaust systems shall be designed to include fire and smoke safety controls (NFPA 91-2004, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Non-Combustible Particulate Solids*). Kitchen exhaust ductwork systems shall be designed to include all fire and smoke safety controls required by NFPA 96-2008, *Standard for Ventilation Control and*

Fire Protection of Commercial Cooking Operations. Engineered smoke pressurization and evacuation systems shall comply with the following:

- NFPA 72
- NFPA 90A
- NFPA 92B
- ASHRAE/Society of Fire Protection Engineers (SFPE), *Principles of Smoke Management*, 2002 (or most recent edition).
- ASHRAE, *Handbook—HVAC Systems and Equipment* (most recent edition).
- International Building Code (IBC)
- Applicable state and local building codes

Special hazard protection systems that initiate an alarm shall be in accordance with the provisions in Chapter 7, *Electrical Requirements* and Chapter 9, *Fire Protection* (particularly Section 9.2.1) of this Manual.

8.3.5 Gas-Fired AHUs

Gas-fired AHUs 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. AHUs with direct-fired gas burners shall not be used, because combustion gases may combine with the fresh air stream. AHUs with indirect-fired gas burners may be considered.

Gas-fired AHUs shall have controls that lock out the gas supply under the following conditions:

- Main flame 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.

8.3.6 Cooling Tower and Water-Cooled Condenser System Controls

Cooling tower controls shall conform with NFPA 214-2005, *Standard on Water-Cooling Towers*. Design of cooling tower fans shall consider use of variable-speed drives (VSD) where feasible (or if not feasible, two-speed motors and on/off controls) to reduce power consumption while maintaining required condenser water temperatures. 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 appropriate 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(s). The design shall provide basin temperature-sensing devices and, if the cooling tower is operated under freezing conditions, additional heat and control system components to maintain cooling tower sump water temperatures above the freezing point.

8.3.7 Simultaneous Heating and Cooling

The BAS shall be designed to minimize the use of reheat in varying humidity conditions and to support minimization of winter cooling requirements. In general, the BAS shall not be configured so as to control comfort conditions within a space by reheating or re-cooling supply air, or by concurrently operating independent heating and cooling systems to serve a common zone. Exceptions may be made, but only under the following circumstances:

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

8.4 Set Point Reset Controls

Systems supplying heated or cooled air to multiple zones must include controls that automatically reset supply air temperature, as required by building loads or by outdoor air temperature. Systems supplying heated and/or chilled water to comfort conditioning systems must also include controls that automatically reset supply water temperatures, as required by:

- Changes in building loads
- Outdoor air temperature
- Changes in return water temperature.

The BAS shall be configured to maintain compliance with the requirements for thermal comfort of occupants contained in ASHRAE 55-2004, *Thermal Environmental Conditions for Human Occupancy.*

Summer and winter space or zone humidity and temperature control shall be provided only on a space-by-space or zone-by-zone basis, and not for the entire ventilation system (unless required to maintain specific humidity and temperature conditions, as stated in the project requirements). The BAS can provide occupants with control over their zone set points, but the range of set point adjustment should be limited to reduce the impact on feedback systems. For certain systems (e.g., under-floor air delivery systems with adjustable controls at each workstation), users may be given greater control of ventilation air delivery. The HVAC systems nighttime setback shall be controlled by a digital timing algorithm. Areas that have excessive heat gain or heat loss, or those significantly affected by solar radiation at different times of the day, shall be independently controlled.

The BAS shall also accommodate occupancy control strategies, including:

EPA facilities can earn one LEED-NC 2009 point if individual comfort controls (e.g., adjustable airflow registers, thermostats) are provided for at least 50 percent of the building's occupants.

- Infrared or ultrasonic occupancy sensors to actuate lighting
- Carbon dioxide (CO_2) sensors to actuate ventilation airflow.

In addition, an interface between the lighting occupancy sensors and the zone temperature set point can make a significant contribution to energy efficiency and should be considered during design. In a temporarily unoccupied zone, the temperature set point range can be broadened slightly to "float," subject to the nature of the work performed in the space. The set point range would then be returned to the normal tolerance range when the zone is reoccupied (as indicated by actuation of lighting).

Supply air fans on VAV systems are typically controlled to maintain static pressure in the duct system at a given set point. For systems with DDC of individual zone boxes reporting to the BAS, the static pressure set point shall be reset based on the zone requiring the most pressure (ASHRAE 90.1-2007).

8.5 Energy Management and Conservation

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

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

HVAC control algorithms shall include optimized start/stop for chillers, boilers, AHUs, and all associated equipment and feed forward controls. The optimized start/stop mode, which is controlled based on predicted weather conditions, aids in minimizing equipment run time without letting space conditions drift outside comfort set points. It accomplishes this objective by internally calculating:

- The earliest time that systems can be shut down prior to the end of occupancy hours
- The latest time that systems can start up in the morning.

This data is then used to automatically establish the operating schedules for heating and cooling systems. Weather prediction programs shall be provided with the BAS software; these programs store historic weather data in the processor memory and use this information to anticipate peaks or part-load conditions. Economizer cycles and heat recovery equipment shall also be controlled based on the weather prediction algorithms.

The BAS shall have the capability to allow building staff to measure energy consumption and monitor performance, which is critical to the overall success of the system. Some or all of the following electrical parameters should be measured and monitored:

- Volts
- Amperes
- Kilowatts
- Kilovolt-amperes
- Kilovolt-amperes, reactive power
- Power factor
- Kilowatt-hours
- Frequency
- Percent total harmonic distortion.

Refer to Chapter 7, *Electrical Requirements*, of this Manual for requirements for separate metering of power consumption.

Energy management measurements shall be totalized and trended in both instantaneous and time-based numbers for all chillers, boilers, AHUs, and pumps. Energy monitoring data shall be automatically converted to the standard database and spreadsheet formats used by EPA and transmitted to a designated workstation(s) or web site. Energy points are those points that are monitored to ensure compliance with ASHRAE 90.1.

EPA facilities can earn three LEED-NC 2009 points by implementing a Measurement and Verification program for building energy systems. Two options are allowed, both of which rely on Volume III of the International Performance Measurement and Verification Protocol (IPMWP), April 2003. Additional detail is provided in the LEED Reference Guide.

All utilities (e.g., electricity, natural gas, fuel oil, makeup and cooling water) shall be metered and tracked by the BAS. All meters shall be provided with signaling devices and shall interface with the building HVAC control panel. Advanced metering of electricity is currently required at all federal facilities (§103 of the Energy Policy Act of 2005 [EPAct]), and advanced metering of district steam and natural gas will be required as of October 1, 2016 (§434 of the Energy Independence and Security Act of 2007 [EISA]) ("advanced metering" is defined as meters that transmit data to a central location at least daily and take measurements of energy consumption at least hourly [EPAct]).

Sub-metering of critical and/or high energy use systems (e.g., lighting) should be strongly considered. Sub-metering requirements for water are discussed in Section 8.5.1 below.

8.5.1 Measurement and Verification Sub-Metering for Water Usage

Permanently installed water meters should be installed for all major water users, retrofit projects, and tenant organizations at federal facilities (Executive Order 13423 Implementing Instructions).

Examples of processes for which sub-metering should be considered include the following:

- Boiler makeup water

EPA facilities seeking certification under LEED-NC 2009 must reduce their water usage by at least 20 percent below the applicable commercial water use baseline (i.e., it is a prerequisite). Facilities can earn additional points by decreasing their water use by 30 to 40 percent (or greater) below the same commercial water usage baseline.

- Contact and non-contact cooling water (e.g., cooling towers)
- Irrigation water
- Rinse water for laboratory spaces
- Supply water for sterilizers and autoclaves
- Dishwashers
- Automatic animal watering
- Photography development tanks
- Venturi siphons for laboratory filtration control systems.

In general, meters should be installed wherever practicable and especially on water supply flows that:

- Are considerably greater than that uses for normal sanitary purposes
- Are intermittent and thus difficult to estimate based on normal water use factors
- For which few or no reliable water use factors are available from other federal facilities or from the literature.

Chapter 6, *Mechanical Requirements*, of this Manual contains additional information regarding water efficiency technologies and measures. It discusses technical requirements for water metering equipment at EPA facilities. The Federal Energy Management Program (FEMP) has also prepared a *Guidance for Developing Baseline and Annual Water Use* (http://www1.eere.energy.gov/femp/program/waterefficiency_baseline.html), which offers generic guidelines for meters and metering for energy projects. Many of the guidelines are also applicable for sub-metering of water uses.

8.6 Maintenance Scheduling

The BAS shall include control programs that switch pumps and compressors from operating mode to standby mode on a scheduled basis. In addition, programs that provide generic preventive maintenance (PM) schedules for building systems and equipment shall be included, complete with information on which parts, tools, and other resources are required to perform the necessary PM tasks. The systems shall be configured to allow easy calibration and recalibration of all sensors and actuators installed to measure and respond to the parameters listed in Table 8-2 above.

9. FIRE 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 101A, the alternatives allowed for sprinklered space may be applied. Existing facilities shall be provided with sprinkler protection under the criteria presented in Section 9.3.1.1.

All sprinkler systems shall comply with NFPA 13 and constructed of components approved by Factory Mutual or listed by Underwriters Laboratories (UL) or another nationally recognized testing laboratory. 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 the International Building Code (IBC) and shall not be used as a substitute for them except where water is not available for sprinkler protection. As used in this document, a Licensed Fire Protection Engineer shall have a valid Professional Engineering License in Fire Protection Engineering and shall meet the requirements of the Society of Fire Protection Engineers Member Grade or equivalent.

9.1 Coatings and Interior Finishes

9.1.1 Intumescent Coatings

Intumescent coating shall not be used to increase the fire resistance rating of any component. Use of intumescent coatings for specialized situations or applications must be approved by a Licensed Fire Protection Engineer and/or EPA SHEMD. Any intumescent coating utilized for special applications must be FM approved or listed by a recognized testing laboratory. Coating must be applied and maintained in accordance with the manufacturers recommendations and the product listing.

9.1.2 Interior Finishes

When selecting interior finish materials, NFPA 101, IBC and state and local codes should be consulted and the most stringent requirements applied. If code requirements are less stringent than those presented in this Section, the requirements of this section shall apply.

9.1.2.1 Interior Finishes

Interior finish ratings are derived from American Society for Testing and Materials (ASTM) E84 and NFPA 255. For any existing construction that is not protected throughout by a sprinkler system that meets 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 the EPA shall be protected throughout by a sprinkler system that meets the Government's approval; and therefore, may have an interior finish of Class B (flame spread 26-75, smoke developed 0-450), unless otherwise restricted by an applicable code (NFPA, IBC, state or local). The most restrictive requirement of these codes shall govern.

9.1.2.2 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 NFPA 101.

9.1.2.3 Fire Safety

Interior floor finishes shall be in accordance with applicable codes 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).

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. To the extent practicable, consolidated and/or reprocessed latex paint consistent with EPA's Comprehensive Procurement Guidelines (CPG) guidance should be used.

9.1.2.4 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:

- The treated material shall be installed in full accordance with the manufacturer's instructions
- 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).
- The treated material is listed by UL or other nationally recognized testing laboratory.

Fire retardant surface treatments may be used to reduce the risks associated with existing conditions, in accordance with applicable codes. 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 as set forth in the most stringent of the applicable codes.

9.1.2.5 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 E84.

9.1.2.6 Ceilings, General

Ceilings shall be set at a minimum height of 9.67 feet 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 E84) in unsprinklered buildings. Protrusion of fixtures into traffic ways is not allowed. Refer to the *Safety Manual* for fire -resistance requirements for ceilings.

9.1.2.7 Ceilings Not Along Exit-Access Path

In sprinkler-protected buildings, ceilings 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.

9.1.2.8 Ceilings Along Exit-Access Path

In sprinkler protected exit ways or enclosed corridors leading to exits, ceilings may be composed of materials with an interior finish 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.

9.2 Fire Alarm Systems

Fire alarm systems must be installed in accordance with Article 760 NFPA 70and NFPA 72. Devices that activate fire alarm systems and evacuation alarms must be completely separated from other building systems such as environmental monitoring systems, building automation system, and security systems. Other features of the fire alarm system (e.g., fan control or 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 fire alarm control panel or sub-panel (e.g., computer room smoke detection). Activation of the main fire alarm shall also activate the audible (and visual, if applicable) devices of the auxiliary fire alarm control panel or sub-panel in the associated alarm area. The fire alarm system shall be in compliance with the most recent codes and publications, as listed below (see other sections for additional codes and standards):

- NFPA 13
- NFPA 14
- NFPA 70
- NFPA 72
- NFPA 90A
- NFPA 101
- NFPA 101A
- PBS-P100 (2005 or most recent version)
- Uniform Federal Accessibility Standards (UFAS) and Architectural Barriers Act Accessibility Standards (ABAAS)
- EPA Facilities Manual Volume 3: Safety and Health Requirements, Chapter 2.
- International Building Code (IBC)
- International Fire Code (IFC)
- State and Local codes.

9.2.1 Fire Alarm System Requirements and Components

9.2.1.1 General System Requirements

Manual fire alarm boxes shall be installed adjacent to all exit doors and all doors to exit stairs. Automatic smoke and temperature rise detectors shall be installed as required by all applicable national and local codes. Activation of a manual fire alarm box or any of the automatic detectors shall initiate the fire alarm system throughout the building or the building zone, and shall send an alarm signal to the central station service. Activation of any automatic fire suppression system (sprinkler or chemical) shall set off the fire alarm as described for a manual fire alarm box, but will also send a suppression activated signal to the local fire department via central station service.

The fire alarm system shall be totally supervised. All 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 central station service, 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 to the central station service and to the building's fire alarm control panel. For non-addressable fire alarm systems, the building shall be divided into fire zones. For non-addressable fire alarm systems, ensure each elevator lobby on each floor, each elevator machine room (if more than one), and each elevator hoistway (when equipped with sprinkler protection) is individually zoned.

Unless the most recent edition of NFPA 101, IBC, or state and local codes have 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 are equal to or larger than 30,000 square feet

Storage occupancies equal to or larger than 100,000 square feet shall have fire alarm systems. All other occupancies shall follow the requirements in the IBC.

9.2.1.2 Central, Local, and Proprietary Alarm System

The building(s) shall be protected by a central station service, remote supervising station, or proprietary supervising station, fire alarm system. Location of manual fire alarm boxes, audible devices, 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. Visible notification devices shall be installed in accordance with the Americans with Disabilities Act (ADA) and the International Building Code (IBC).

9.2.1.3 Manual Systems Input

Where required, each system shall provide manual input from manual fire alarm boxes, which shall be located in exit or public corridors adjacent to each stairway and to each exit from the building. Additional stations will be required at any location where there is a special risk or where the travel distance to the nearest station exceeds 200 feet. For new installations, manual fire alarm boxes shall be installed within 5 feet of exit doors. For existing installations, manual fire alarm boxes shall be provided in the natural exit access path or within 5 feet of exit doors. As a general principle, the manual fire alarm box shall be placed so that a person using it will be between the fire and the exit. When required by the IBC, emergency telephone service shall be provided at each elevator lobby, each floor level of exit stairs, each elevator, and when constructed, at the emergency command center.

9.2.1.4 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 approved by SHEMD. Detection shall be provided where a preaction or deluge sprinkler system exists. Automatic sprinkler protection requirements are described in Section 9.3, of this Manual

- 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 of a fire suppression agent (NFPA 72)

- 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 required, they shall be installed in accordance with NFPA 72

- Special hazard protection systems shall initiate an alarm in the building. These special systems include, but are not limited to, dry, wet chemical, or clean agent extinguishing systems as well as specialized fire detection equipment such as air-sampling 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

    - Malfunctioning of the fire protection system battery back-up system

    - Failure of one of the circuits/channels that carries the fire alarm signal to the remote, constantly manned Central Monitoring Station

    - Loss of air pressure for dry-pipe sprinkler 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.)

- Trouble signals shall be transmitted under each of the following conditions:

  - 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.)

  - 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)

  - Loss of a central processing unit (CPU) or of CPU peripheral equipment in a multiplex system.

9.2.1.5 Automatic Systems Output

The signal to all alarm condition indicating devices, the Central Monitoring Station, and all equipment, fire doors, etc., that respond to a fire alarm shall be transmitted automatically once a manual pull box, waterflow switch, detector, or any other alarm initiating device 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.

- 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

- 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, the IBC, and Title III standards of ABAAS 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 the Safety, Health and Environmental Management Division (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 transmitted to the central station for an entire building. Refer to the automatic systems input information in subsection 9.2.1 above for required supervisory conditions.

Additional automatic actions shall be performed for smoke control, elevator recall, and door closings. Smoke control and elevator recall shall be coordinated with the evacuation plan for a building. (A summary of system actions is shown in Table 9-1.)

Table 9-1: Fire Protection Status Conditions

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 elevator recall		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		X		
Cause visual alarm signal throughout the building	X	X		X		

Input device codes:
A = Manual fire alarm box
B = Smoke detectors (other than duct)
C = Duct smoke detectors
D = Water flow detectors and automatic extinguishing systems
E = Supervisory device
F = Emergency telephone
* Only smoke detectors associated with the elevators (e.g., the elevator lobby or machine room) may initiate elevator emergency operation.

9.2.1.6 Manual Systems Output

Any action that can be performed automatically must be able to be initiated manually from the command center or fire alarm system control panel. A smoke control panel designed in accordance with the IBC shall be provided when smoke control systems are provided. The command center, or fire alarm system control panel, shall have the capability of canceling and restoring any action that has been initiated automatically or manually.

9.2.1.7 System 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
- Ring-back feature when a silence switch for audible trouble signal is provided.

9.2.1.8 High-Rise Systems Features

For high rise buildings, 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 and NFPA 72.

9.2.1.9 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, notification appliance circuits and signal line circuits will remain functional.

9.2.1.10 Code Compliance, Manual System

A complete, code-complying fire alarm system shall be designed. For small buildings, such as those that do not require automatic fire suppression of fire detection systems or those with a low occupant load, and where allowed by code, the system may be a manual system only. The manual system shall include manual pull boxes, fire alarm annunciator signals, and an annunciator panel indicating the zone where the alarm was initiated. The alarm shall be sent to a central station service.

9.2.1.11 Code Compliance, Automatic System

In large facilities, or where required by code (NFPA 101, NFPA 72, and the IBC),, the systems shall be automatic and shall include smoke detectors, manual fire alarm boxes, rate of rise detectors, alarm bells,horns and speakers and strobe lights, and a central annunciator panel. Suppression systems shall be tied to the central annunciator panel. The fire alarm system shall be tied to a central station service in the area.

9.2.1.12 Central Station Service

The building(s) shall be protected by a local fire alarm system(s) connected to either a fire department station or a UL-listed central station service unit meeting the requirements of NFPA 72.

9.2.1.13 Fire Zones

Building(s) shall be subdivided into fire zones as recommended by IBC, NFPA fire suppression, detection, and alarm codes, 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).

9.2.1.14 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). In addition, the fire alarm system wiring shall meet the requirements of GSA PBS P-100 for fire alarm survivability:

- Two vertical risers (i.e., supply and return interconnected network circuits Style 7-Class A) shall be installed as remote as practicable from each other so that a single fire will not involve both risers.
- The two vertical risers shall be protected by a minimum 2-hour rated enclosure or an approved 2-hour rated cable or system, not common to both vertical risers.
- The horizontal interconnection between the two vertical risers at the top and bottom shall be protected by a minimum 2-hour rated enclosure, or an approved 2-hour cable or system, or an approved construction material having a 2-hour fire resistance rating.
- A minimum of two (2) distinct fire alarm audible notification appliance circuits and a minimum of two (2) distinct visible notification appliance circuits shall be provided on each floor.
- Adjacent fire alarm audible and visible notification appliances shall be on separate circuits.

Fire Command Center

General. The fire command center shall meet the

9.2.1.15 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 fire alarm box. Additional information on door requirements may be found in Section 4.9, Building Openings, of this Manual. Maintenance, operation, testing, and equipment shall conform to NFPA 72 and NFPA 70.

9.2.1.16 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 (alternating current) supply, loss of stand-by generator power, low battery voltage, removal of alarm zone module (card, printed circuit 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.

9.2.2 Emergency Power

Emergency power shall be provided for the fire alarm system in accordance with NFPA 72, NFPA 101, and Chapter 7, *Electrical Requirements,* of this Manual. 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.

9.2.3 Carbon Monoxide Detectors

Carbon monoxide detectors and detection systems shall be allowed to be transmitted to the fire alarm system as a supervisory signal. Carbon monoxide detectors and detection systems shall be installed and maintained per NFPA 72.

9.2.4 Fire Command Center – High Rise

Where required by the IBC, state or local codes, or NFPA 101, the building must have a fire command center where fire-related control panels are located. The fire command 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. If the command center cannot practically be located at the main entrance, coordinate its location with the local fire department and SHEMD. Fire command centers shall comply with the applicable requirements of NFPA 101 and the IBC. Fire command center layout, size, and all features provided shall be submitted to SHEMD and the local fire department for approval prior to construction of the center. Features provided in the command center shall be as required by NFPA 101 and the IBC.

9.3 Fire Suppression and Firefighting Systems

9.3.1 Sprinklers

9.3.1.1 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. The need for a preaction system shall be determined on the basis of review and recommendation by a licensed fire protection engineer and/or SHEMD. 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 101A, the alternatives allowed for sprinklered space may be applied.

In addition to the IBC requirements, atrium sprinkler systems shall be designed as a separate sprinkler zone. In addition, a separate manual isolation valve and a separate water flow switch shall be located in an accessible location. A tamper switch shall be provided on all such valves.

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 occupable story

- Throughout occupancies exceeding the area or height limitations allowed by the IBC

- In all areas below grade that meet the definition of "windowless" in IBC

- 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 IBC

- In cooling towers with more than 2,000 cubic feet of a combustible fill when 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; or the value of the cooling tower is five or more times the cost of installing the sprinkler protection

- 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 electronic equipment operation areas, including data storage areas.

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.

9.3.1.2 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 waterflow alarm systems connected to the fire alarm system

9.3.1.3 Wet Pipe

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

9.3.1.4 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 compute demands for comparable wet-pipe systems. In areas subject to freezing, install dry-pipe sprinkler systems, dry pendent sprinklers, or provide heat in the space, and/or reroute the sprinkler piping. Heat tape shall not be used on sprinkler piping. Where the unheated area is small, it may be cost-effective to install dry pendant sprinklers. Antifreeze systems shall not be installed in any new construction or renovation projects.

9.3.1.5 Preaction

A preaction system shall be used where it is particularly important to prevent the accidental discharge of water. Each laboratory room protected by a preaction system shall be provided with an individual isolation valve. The need for a preaction system shall be determined on the basis of review by, and recommendation of a licensed fire protection engineer. The detection system chosen to activate the preaction valve shall have a high reliability and shall be equipped 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.

9.3.1.6 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 quicker response is required, an ultra high speed deluge system or explosion control system may be required.

9.3.1.7 Quick Response

Quick-response sprinklers must be used in new installations except where prohibited by NFPA 13 or GSA PBS-P100 such as high temperature areas as defined by NFPA13. PBS P-100 presents elevator machine rooms as an example of such an area. 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 sprinklers should be limited to applications for which they have been specifically listed (e.g., UL, Factory Mutual Laboratory).

9.3.1.8 Water Spray

Installation of water spray systems shall comply with NFPA 15.

9.3.2 Carbon Dioxide

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

9.3.3 Dry Chemical

Systems shall comply with NFPA 17 and the following:

- **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 9.2 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. Pre-engineered systems that fail to discharge these amounts will be considered unsatisfactory.

9.3.4 Foam

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

9.3.5 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.

9.3.6 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.

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.

9.3.7 Portable Fire Extinguishers

Portable fire extinguishers shall be provided, located, and mounted in accordance with NFPA 10. 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 (2005 or most recent version), 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, uninterruptible power supply 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.

9.3.7.1 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.

- 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.

9.4 Gaseous Fire Suppression Systems

9.4.1 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 EPA's Significant New Alternatives Policy.

9.4.2 Clean Agent and Carbon Dioxide 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 EPA Architectural, Engineering, and Asset Management Branch (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 fire protection 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 9.2, Fire Alarm, of this Manual for fire alarm requirements. Design shall incorporate zone purge capability for post discharge use at a rate of not less than 6 air changes per hour.

- **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 NFPA 2001.

9.5 Operation and Codes

Operation and maintenance instructions and system layouts shall be posted at the control equipment or kept on file in the building maintenance engineers' office. 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.

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.

9.6 Main Firefighting Water Supply

A dependable public or private water supply capable of supplying the required flow for firefighting shall be provided for all new construction and renovation projects. For buildings located in rural areas where established water supply systems for firefighting are not available, the water supply shall be obtained from a tank, reservoir, or other reliable source.

Domestic water distribution systems that also supply firefighting water shall also be capable of:

- Delivering a peak domestic flow of 2.5 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)

- Satisfying firefighting flow requirements plus 50 percent of the average domestic requirements, plus any additional demands (e.g., process water, cooling water) that cannot be reduced during a fire.

☐Where domestic water distribution systems must serve internal fire protection systems (i.e., sprinklers or foam systems), adequate residual pressures shall be maintained for proper operation of these systems.

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.

☐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 the 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.

9.6.1 Fire Hydrants

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.

Each fire hydrant within the distribution system must be capable of delivering 1,000 gallons per minute at a minimum residual pressure of 20 psi. Fire hydrant branches (from main to hydrant) shall be not less than 6 inches in diameter and 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 not be located more than 300 feet from the buildings to be protected. Each building shall be protected by at least two hydrants.

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.

9.6.2 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 required 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.

9.7 Egress

The building subdivisions and the arrangement of exits, corridors, vestibules, lobbies, and rooms shall conform to requirements of the most recent edition of NFPA 101, the IBC, 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. . In addition to the aforementioned codes, means of egress for laboratory facilities shall comply with the requirements set forth in NFPA 45. The facility, buildings, and interior modules shall have controllable access, which should ensure a reasonably safe and secure working environment.

9.7.1 Egress Routes

Egress routes including exits and exit access shall comply with NFPA 101. Corridors, stairs, ramps, and other means of egress components shall meet the minimum width requirements set forth by NFPA 101.

9.7.1.1 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 Chapter 6, *Mechanical Requirements*, of this Manual.

Unless otherwise noted, all doors shall be a minimum of 36 inches wide. Doors in designed egress ways shall swing in the direction of egress. Door leaf encroachment into any means of egress shall comply with the requirements of NFPA 101. Doors and windows shall conform to requirements of NFPA 80, as applicable.

Exit doors shall be equipped with “panic hardware” (i.e., cross bars or push pads) that meet all applicable requirements of NFPA 101, including the ability to open the door with 15 pounds force or less. Only approved panic hardware shall be used on door assemblies that are not fire-rated door assemblies. Only approved fire exit hardware shall be used on fire-rated door assemblies.

9.7.2 Lighted Exit Signage and Exit Markings

The requirements for exit lighting and marking are contained in NFPA 101, PBS P-100, 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 NFPA 101. . All means of egress components shall provide adequate illumination in accordance with the requirements of NFPA 101. Also see section 7.7.1 “Emergency Lighting”.

Internally illuminated signs shall meet the following criteria:

- Emergency lighting for the area shall conform to Occupational Safety and Health Administration and NFPA 101 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
- All exit signs manufactured on or after January 1, 2006 must have an input power demand of 5 watts or less per face
- When procuring energy consuming products, EPA shall procure either ENERGY STAR (http://www.energystar.gov/index.cfm?fuseaction=find_a_product.) FEMP-designated products (http://www1.eere.energy.gov/femp/technologies/procuring_eeproducts.html) (EPAct 2005, Section 104)

Many exit signs contain tritium, the radioactive form of hydrogen. Using tritium in exit signs ensures that the sign will remain illuminated in the event of an electrical outage or a fire. If the tubes in the exit signs are severely damaged, the tritium, which exists in the sign as a high temperature gas, might escape. The main hazard associated with tritium is internal exposure by inhalation or if it enters the body through an open wound or are absorbed through the skin. Personnel should not handle damaged exit signs.

9.7.3 Photoluminescent Materials

9.7.3.1 Exit Stair Identification Signs

The following requirements take precedence over the requirements in NFPA 101:

- Stair identification signs shall have a photoluminescent background complying with Standard Specification for Photoluminescent (Phosphorescent) Safety Markings ASTM E2072-04 as a minimum standard.
- The signs shall be a minimum size of 18 inches by 12 inches.
- The letters designating the identification of the stair enclosure shall be a minimum of $1^1/_2$ inches in height.

- The number designating the floor level shall be a minimum of 5 inches in height and located in the center of the sign.

- All other lettering and numbers shall be a minimum of 1 inch in height.

- The directional arrow shall be a minimum of 3 inches in length.

9.7.3.2 Exit Stair Treads

The following requirements take precedence over the requirements in the NFPA 101:

- Stair treads shall incorporate a photoluminescent stripe that is either an applied coating, or a material integral with, the full width of the horizontal leading edge of each stair tread, including the horizontal leading edge of each landing nosing.

- The width of the photoluminescent stripe shall be between 1 inch and 2 inches.

- The width of the photoluminescent stripe, measured horizontally from the leading edge of the nosing shall be consistent at all nosings.

- The photoluminescent materials used shall comply with ASTM E2072-04 as a minimum standard.

9.7.3.3 Exit Stair Handrails

The following requirements take precedence over the requirements in the NFPA 101:

- Stair handrails shall incorporate a photoluminescent marking that is either an applied coating, or a material integral with, the entire length of each handrail.

- The photoluminescent handrail marking, at a minimum, shall be located at the top surface of each handrail, having a minimum width of $^1/_2$ inch.

- The photoluminescent handrail marking shall stop at the end of each handrail. If the handrail turns a corner, the marking shall continue around the corner.

- The photoluminescent materials used shall comply with ASTM E2072-04 as a minimum standard.

9.8 Special Spaces and Equipment

9.8.1 Records Centers

Records centers shall comply with NFPA 232 and the Track File requirements of PBS GSA handbook PBS-P100 (2005 or most recent version).

9.8.2 Laboratories and Chemical Storage Areas

Chemical laboratories and chemical storage areas shall comply with NFPA 45, NFPA 30, and GSA Publication PBS-P100 (2005 or most recent version).

9.8.3 Storage Tanks for Fuels and Flammable Liquids

Storage tanks for fuels and flammable liquids shall comply with NFPA 30.

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. 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. Non-vented 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 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 feet (17.6 meters)
- The design velocity of the duct should not be less than 2,000 feet per minute per Table 3-2, *Industrial Ventilation, 22nd Edition.*
- The cabinets shall be marked in conspicuous lettering *“Flammable—Keep Fire Away.”*

Refer to Chapter 5 of *Volume 4, Environmental Management Guidelines* for additional information on storage tanks.

9.8.4 Storage Tanks for Compressed Gases

Storage tanks for compressed gasses shall comply with:

- NFPA 54
- NFPA 55
- NFPA 58

9.9 Security Considerations

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.

Locking of doors within the means of egress for security is permitted provided the egress door locks meet the requirements of NFPA 101.

10. SPECIALTIES

10.1 Furnishings

EPA recommends systems furniture (or "cubicles") for workstations, because they provide flexibility in space planning and in function; that is, workstations can be configured to suit the particular functional needs of the office. In order to meet that need, EPA promotes the use of open-plan arrangements for all applicable projects. Free-standing furniture, such as desks, conference tables, and credenzas, are issued only in the enclosed offices for senior management positions. Special-purpose spaces, such as food service facilities, libraries, conference/training centers, and similar rooms will require free-standing furniture appropriate to the space function.

The choice of a particular furniture system is also dependent on federal procurement regulations, which require that the procurement process be open and competitive such that all competent manufacturers have the opportunity to submit an offer. For this reason, it is important for EPA (and its design consultants) to prepare detailed specifications providing the performance criteria for the furniture.

EPA follows the Environmentally Preferable Purchasing (EPP) Program and Comprehensive Procurement Guidelines (CPGs). Furnishings shall be environmentally assessed based on the materials origin, recycled content, the manufacturing process and emissions. Wherever possible, refurbished or remanufactured furniture is recommended. An example of the testing protocol, chain-of-custody requirements, packing/shipping instructions, and the manufacturing assessment instrument used for the Potomac Yards project are available on EPA's web site, at http://www.epa.gov/greeningepa/facilities/hq_nova.htm

Furnishings are discussed more extensively in Volume 1 of the EPA Facilities Manual, *Space Planning and Acquisition Guidelines*. Additional information on environmentally preferred specifications for furniture can be obtained from the Sustainable Facilities Practices Branch (SFPB).

10.2 Visual Display Boards

The term visual display board includes presentation boards, marker boards, tackboards, board cases, display track system and horizontal sliding units. Visual display boards shall be from a manufacturer's standard product line.

The designer has the option to require that visual display boards for a project be provided by one manufacturer when appropriate. Manufacturer's standard performance guarantees or warranties that extend beyond a one year period shall be provided. Finish colors for required items shall be as specified in the drawings.

10.2.1 Markerboards

Markerboards, also known as whiteboards, provide a writing surface for the conveyance of information. Most markerboards are colored white and are coupled with felt-tip non-permanent markers that allow for erasable markings to be made. Markerboards are composed of enamel-on-steel, which creates a magnetic surface whereby paper can be posted by means of magnets. Markerboards can also be used as a projecting medium. Increasingly, interactive whiteboards are being utilized whereby a computer and a projector connect to the whiteboard and allows for the capturing of notes and the integration of computer software onto the markerboard's surface. The benefits of markerboards, in comparison with chalk boards, is that there is no chalk dust, which can prompt allergic reactions and be problematic for dust-sensitive equipment. Chalkboards shall not be used in EPA facilities.

The markerboard shall be equipped with a marker tray that shall be the same material as the frame, extending the full length of the markerboard. Dry erase markings shall be removable with a felt eraser or dry cloth without ghosting. Each unit shall come complete with dry erase markers and a felt eraser. Due to their light-weight construction, markerboards can be easily hung on any wall and can be framed with plastic, aluminum, or wood. Locations of markerboards shall be determined by the design professional.

10.2.2 Tack Boards

Cork is the traditional medium for tack boards and because it is a renewable resource, it is an environmentally-friendly product. The substrate for some tackboards is made from recycled paper and paraffin. Cork is available in sheets or tiles of various thickness. It is tackable, self-healing, durable, sound absorbing, and naturally resistant to moisture, rot, mold, and fire. Tack boards with renewable or recycled content should be used, whenever possible.

10.3 Interior Signage Systems and Building Directory

All general interior signage and door identification signs must comply with the requirements of 29 CFR 1910.145 and other hazard-specific OSHA standards, where applicable.

Interior signage systems and building directories will be accessible in accordance with the Architectural Barriers Act Accessibility Standards (ABAAS). In combination with this specification, drawings and attachments will include location, dimensions, elevations, schedules, content, details and such other information as required to indicate the extent of the work.

Building directories shall be lobby directories or floor directories, and shall be provided with a changeable directory listing consisting of the areas, offices and personnel located within the facility. Dimensions, details, and materials of sign and message content shall be shown on the drawings, attachments, and signage placement schedule.

Signs, plaques, and dimensional letters shall be the standard product of a manufacturer regularly engaged in the manufacture of such products and shall essentially duplicate signs that have been in satisfactory use at least two years prior to bid opening. Signage inserts should be produced on local computers and printers. These inserts are preferred over inserts produced from an outside source.

Interior signage shall be of the design, detail, size, type, and message content shown on the drawings/attachments/signage placement schedule (as applicable); shall conform to the requirements specified; and shall be provided at the locations indicated. Signs shall be complete with lettering, framing as detailed, and related components for a complete installation. Signage shall be obtained from a single manufacturer with edges and corners of finished letterforms and graphics true and clean. Recyclable materials shall conform to EPA requirements in accordance with Section 01 62 35 of the Unified Facilities Guide Specifications on Recycled/Recovered Materials. Table 10-1 below provides a synopsis of the EPA's recommended recycled/recovered materials content ranges for signage systems:

Table 10-1: EPA CPGs for Signage Systems

Item/Material	Post consumer Content (%)	Total Recovered Materials Content (%)

Aluminum signs	25	25
Plastic signs	80 – 100	80 – 100
Plastic sign posts Supports for plastic sign posts	80 – 100	80 – 100
Steel sign posts Supports for steel sign posts	16 67	25 – 30 100

The product selection process will be as follows: The EPA Project Manager will first determine whether the proposed signage product meets the above-described requirements and any additional project-specific requirements. If multiple products fulfill the requirements, the product will be selected based on a combination of the following factors: aesthetic values, appearance, cost, and environmental benefits (e.g., recycled content).

Use of personal names in interior signage is discouraged. If personal names are required, changeable message strips will be used. Consider coordination of interior signage within this specification with future signage required on individual workstations.

10.3.1 Door Identification

Door identification shall be installed in approved locations adjacent to office entrances. The type of door identification must be approved by the design professional. 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. Each exit sign must be illuminated to a surface value of at least 5 footcandles (54 lux) by a reliable light source and be distinctive in color. Each exit sign must have the word “Exit” in plainly legible letters not less than 6 inches (15.2 centimeters [cm]) high, with the principal strokes of the letters in the word “Exit” not less than $^{3}/_{4}$ inch (1.9 cm) wide.

10.3.2 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 design professional for review and approval before construction documentation begins.

10.3.3 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 design professional.

10.4 Laboratory Casework

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 direction of that manufacturer. The laboratory casework design should meet the functional, aesthetic, adaptable, and maintenance needs of the scientists and technicians who will be using the labs. Performance set forth herein shall establish minimum standards for design, performance, and function. Products that fail to meet these standards will not be considered.

Unless otherwise noted, 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.

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.

Design of laboratory casework (cabinets, counters, fume hoods) should be coordinated and compatible with architecture and engineering professionals as well as the scientists and technicians who will be using the labs. 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 design professional.

10.4.1 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.

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, the structure should allow for the placement of 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 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.

10.4.3 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.

10.4.4 Shelving

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 or similar performing material.

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.

Storage shelving for chemicals should be fitted with a raised lip or tilted slightly backward so containers will not slip off the edge. Storage shelving for chemicals should not be mounted significantly higher than eye level, to forestall the risk of an employee upending a container and being showered with a hazardous chemical.

10.4.5 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.

10.4.6 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 drain boards. Casework along walls shall have a 4-inch-high backsplash. Countertops that are bio-based or have recycled-content should be used, whenever possible.

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. 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. 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.

10.4.7 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 in consultation with the HVAC engineer and EPA Safety, Health and Environmental Management Program (SHEMP) representative shall be responsible for determining, with the users of the facility, types and sizes of fume hoods appropriate to their intended use.

Fume hoods must be located away from doors, pedestrian traffic, duct work, and air supply and return outlets. 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.

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 EPA’s Safety, Health, and Environmental Management Division (SHEMD), each laboratory fume hood shall be certified by the hood manufacturer or his qualified representative that it is installed and functions according to specifications.

10.4.8 Environmental Rooms

Environmental rooms shall be of modular, insulated panel construction, providing temperature and humidity control with specified set point 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
- Personnel emergency alarm.

11. DESIGN/CONSTRUCTION-RELATED ISSUES

This chapter provides guidance on certain miscellaneous construction-related processes and procedures not covered in other chapters of this Manual. These include:

- Construction waste/debris recycling
- Assurance of adequate indoor air quality (IAQ) during and following construction
- Building “tightness” testing

11.1 Construction Waste Recycling

In accordance with Guiding Principle V, *Reduce Environmental Impact of Materials*, pursuant to §2(f) of Executive Order (EO)13423, federal agencies are directed to "identify local recycling and salvage operations that could process site-related waste" and to "recycle or salvage at least 50 percent construction, demolition and land clearing waste, excluding soil, where markets or on-site recycling opportunities exist." The Environmental Protection Agency’s (EPA) 2009 *Sustainable Buildings Implementation Plan* establishes an increased goal of recycling at least 75 percent of these waste streams for projects that encompass greater than 20,000 gross square feet (GSF).

All new construction and major renovation projects shall include the separate collection of waste materials of the following types (as appropriate to the project waste and to the available recycling and reuse programs in the project area):

- Land clearing debris
- Asphalt pavement and bituminous roofing shingles
- Gravel and aggregate
- Concrete and masonry
- Metals (e.g., steel, aluminum, copper)
- Wood (e.g., pallets, brush, excess lumber)
- Demolition debris (non-hazardous waste)
- Glass (whole and broken, untempered)
- Plastic film, Styrofoam™, and rigid containers
- Cardboard and paper packaging materials
- Paper (newsprint, white office paper grades)
- Gypsum board
- Non-hazardous excess paint and paint cans
- Insulation
- Carpet and carpet pads
- Acoustical and other ceiling tiles
- Petroleum lubricants, excess and used
- Other non-hazardous solid wastes, as appropriate

Materials shall be segregated, size-reduced (e.g., crushed, shredded, baled), and otherwise prepared in accordance with recycling or reuse facility requirements (e.g., free of dirt, adhesives, solvents, petroleum contamination, and other substances deleterious to recycling process).

Construction projects that also involve demolition of existing structures may require management of additional universal or hazardous waste streams, such as:

EPA facilities can earn one or two LEED-NC 2009 points for recycling or salvaging at least 50 percent or at least 75 percent, respectively, of construction and demolition debris generated from a new construction or major renovation project. (*Note – Current EPA policy requires that projects affecting greater than 20,000 square feet recycle at least 75 percent of C/D debris*).

- Fluorescent lamps (whole or broken)
- Used solvents
- Asbestos-containing materials
- Lead-based paint (and debris coated with lead-based paint)
- Polychlorinated biphenyls (PCBs)-containing electric equipment, such as transformers or capacitors
- Ballasts associated with fluorescent lamp fixtures that may contain PCBs
- Mercury-containing thermometers or switches
- Wood floor blocks containing PCBs, polycyclic aromatic hydrocarbons, and/or heavy metals
- Underground storage tanks and tank sludges
- PCB-containing caulking materials (used to seal doors, windows, concrete joints/seams). Include adjacent porous materials if PCBs have leached into those materials.

All of the above wastes shall be managed in accordance with applicable Resource Conservation and Recovery Act (RCRA) regulations (40 CFR 260 – 280) (and, in the case of PCBs-containing equipment, Toxic Substances Control Act regulations (TSCA) [40 CFR 761]). EPA requires that all used fluorescent lamps be recycled. Used solvents can often be blended and either re-sold or incinerated in RCRA-permitted units for energy recovery. Other waste streams listed usually will require disposal at an approved special waste or hazardous waste landfill, as dictated by RCRA rules.

Where possible, local markets or disposal outlets should be used to reduce greenhouse gas emissions associated with long-haul transportation. This criteria should be factored into the decision-making process, along with other key factors such as environmental compliance (the primary factor), net revenues or costs, capacity to accept materials/wastes from the project, and material specifications/preparation requirements.

11.1.1 Deconstruction

An alternative that is growing in popularity is the pre-demolition removal and salvage of valuable items (commonly known as “deconstruction”). In a deconstruction program, the agency owning the building allows organizations (e.g., salvage companies, Habitat for Humanity) to remove and retrieve items of value from the structure such as architectural details; windows and doors; metal wiring; unused machinery; working heating, ventilation, air conditioning, and refrigeration equipment and ductwork; and old growth hardwoods. In some instances, both the agency and the deconstruction entity share in the revenues from salvage of the items; in others, the government allows the entity to keep all revenues from salvage in exchange for a nominal fee or no fee at all for the deconstruction activities. Another alternative is to donate the items to charitable organizations, which is an allowable alternative under the Federal Property Management Act of 1949.

Deconstruction is highly recommended, and almost all sites will have items whose value justifies a deconstruction and salvage effort. Items left intact and reused will almost always carry more inherent value than scrap items (consider the example of a concrete statue or architectural detail and its accompanying value, compared to crushed-up concrete that can only be used as clean fill). Furthermore, reused items from deconstruction count for 100 percent of their volume or weight toward meeting federal recycling goals, whereas processed materials may or may not be completely marketable.

11.1.2 Returnable Packaging

Where possible, the project shall request that suppliers deliver materials in containers such as reusable crates, tubs, and drums, or commit to taking back disposable packaging materials (e.g., cardboard, plastic film) for recycling. This will reduce the overall volume of waste and provide at least a partial backhaul load (potentially lowering transport costs).

11.1.3 Mobile Equipment/On-Site Processing

Where the quantities justify the rental costs and labor (operators), mobile equipment (e.g., concrete/rubble crushers, wood waste grinders, tire shredders, or even entire picking lines) can be rented and utilized at the job site to produce clean fill, mulch, chipped tires, and other items that can be directly utilized on site. Off-site markets for wood chips or shredded tires provide another alternative if materials cannot be used on site.

11.2 Indoor Air Quality

Source control and ventilation need to be part of diligent IAQ management. It should be noted, though, that ventilation merely addresses the symptoms of indoor air pollution, while source control eliminates the cause. Therefore, in addition to functionality and design, a product's IAQ performance must be one of the primary product features considered in the specifying and purchasing process. This section specifically deals with management of IAQ during and immediately following construction activities. IAQ that is addressed by ventilation after construction is complete is addressed in Chapter 6, *Mechanical Requirements*.

11.2.1 Emissions Control

During construction operations, follow the recommendations in the Sheet Metal and Air Conditioning Contractors' National Association Publication, *IAQ Guidelines for Occupied Buildings under Construction*, including:

- To prevent the building heating, ventilation, and air conditioning (HVAC) system from acting as a conduit for transmission of contaminants, seal return registers of affected spaces during construction operations, provide temporary exhaust during construction operations, and, to the greatest extent possible, isolate and/or shut down the return side of the HVAC system during

EPA facilities can earn two LEED-NC 2009 points by developing and implementing an Indoor Air Quality Management Plan for the construction and pre-occupancy phases of the building (one point for each phase). The required content for these Plans is outlined in the LEED Reference Guide. EPA facilities can also earn one additional LEED-NC 2009 point by implementing certain measures for indoor chemical and pollutant source control. (*The requirements of this section generally parallel those measures; therefore, most EPA projects should be capable of earning these points*.)

construction. When the ventilation system must be operational during construction activities, provide temporary filters

- Provide and use low- and zero-volatile organic compound (VOC) materials (e.g., paint thinners, varnishes, strippers, adhesives and carpet backings, wood products containing formaldehyde) to the extent possible. The term low-VOC is presumed to follow the criteria in SCAQMD Rule #1168

- Isolate areas of work as necessary to prevent contamination of clean or occupied spaces

- Provide pressure differentials and/or physical barriers to protect clean or occupied spaces. Work areas should generally be maintained at a lower pressure than occupied areas by means of separate exhaust fans or balancing centralized airflows to the different areas

- Ensure that vehicular equipment operation areas and materials storage and staging areas for new construction are away from outdoor air intakes for the existing structure

- Temporarily seal building intake dampers when high-emitting construction activities are performed near outdoor air intakes for the existing structure

- In the occupied spaces adjacent to construction area(s), operate the building mechanical system at maximum outdoor air dilution. Provide air changes per hour of 1.5 or more through the building's central ventilation system. Provide supplemental, stand-alone exhaust fans in areas where large quantities of VOCs are being used, as necessary

- Provide a minimum 48-hour pre-ventilation period for packaged dry products prior to installation. Remove materials from packaging and ventilate in a secure, dry, well-ventilated space that is free from strong contaminant sources and residues and ventilated directly to the exterior. Provide a temperature range of 60 degrees Fahrenheit (°F) to 90°F continuously during the ventilation period. Do not ventilate within the work space unless otherwise approved by Project Architect/Engineer

- Provide adequate ventilation during and after installation of interior wet products and interior final finishes

- Provide filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 (as determined by American Society of Heating, Refrigerating, and Air Conditioning Engineers [ASHRAE] 52.2) during construction (MERV 13 during occupancy)

- Schedule construction operations involving wet products prior to dry products, to the greatest extent possible

- Immediately clean up and containerize spilled liquids and contaminated soils and dispose of promptly in accordance with federal and state regulations

- Seal all unnecessary openings in walls, floors, and ceilings (e.g., penetrations for utilities) as soon as practicable

- Control particulate emissions with appropriate equipment (e.g., vacuum-assisted sanders, "wet" saws)

- Do not use gasoline or diesel-powered equipment indoors (use electric equipment instead, wherever available).

11.2.2 Moisture Control

Materials shall be examined for dampness and/or mold when they arrive on site. If acceptable to the Architect/Engineer, damp materials shall be dried completely prior to installation; otherwise, damp materials shall be rejected and returned to the supplier for replacement. While stored on-site and prior to installation, absorptive materials shall be shielded from moisture damage and regularly inspected for dampness and mold growth. Preferably materials will be stored under a roof; materials stored outdoors must be covered with plastic sheeting.

Work shall be scheduled such that absorptive materials (including, but not limited to, porous insulation, paper-faced gypsum board, ceiling tile, fabrics, and finish flooring) are not installed until they can be protected from rain and construction-related water damage. Interior absorptive materials shall be installed only after building envelope is sealed and weatherproofed. Before sealing materials into an assembly, their moisture content shall be tested, in accordance with the procedures outlined below. If satisfactory results cannot be obtained following drying and retesting, said materials shall be removed and replaced with new materials. Roofing materials shall be weatherproofed as quickly as possible following installation, including application of final exterior sealant layers and flashing around penetrations. Relative humidity inside basements and crawlspaces shall be monitored, and the spaces shall be dehumidified whenever relative humidity is greater than 85 percent for more than two consecutive weeks or at the first sign of mold growth. The Architect/Engineer shall verify that final grades of site work and landscaping drain surface water and groundwater away from the building. In addition, the following visual inspections shall be performed:

- Inspect materials as they are being installed/immediately following installation for moisture and dampness. Verify that vapor barriers are installed without punctures and/or other damage and are sealed completely

- Verify correct shingling and installation of flashing for the roof, walls, windows, doors, and other penetrations, and that insulation is installed without voids

- Follow ASTM D7186 to ensure adequate weatherproofing of the roof.

In addition to visual inspections, the following test procedures shall be utilized:

- **Concrete**: Moisture test prior to finish flooring application, in accordance with one or more of the following:
  - ASTM D4263
  - ASTM F1869
  - ASTM F2170

  Unless otherwise indicated, acceptable upper limits for concrete are less than 4 percent (top inch), less than 85 percent headspace relative humidity, and less than 3 pounds of water per 1,000 square feet per day installed

- **Wood**: Moisture test in accordance with ASTM D4444. Unless otherwise indicated, acceptable upper limits for wood products are less than 20 percent at center of piece and less than 15 percent at the surface.

- **Gypsum Board, Gypsum Plaster, Insulation, and Other Absorptive Materials**: The dryness of drywall, plywood floors, and other building materials (not wood framing) must be confirmed qualitatively by comparing moisture readings between like materials in affected and unaffected areas of the building (or inside a nearby unaffected building). Wetted materials are presumed dry when their moisture content readings are within 5 percent of those of like materials in unaffected areas when taken with an intrusive/penetrating moisture meter. (Note: Material moisture results measured from non-intrusive meters may be less accurate than intrusive meters.)**Windows: Test in accordance with ASTM E1105. Unless otherwise indicate**d, **the acc**eptable limit is no leakage for 15 minutes

- **Horizontal Waterproofing (not roofing)**: Test in accordance with ASTM D5957. Unless otherwise indicated, the acceptable limit is no leakage for 15 minutes

- **Masonry**: Test in accordance with ASTM C 1601. Unless otherwise indicated, the acceptable limit is no leakage for 15 minutes

- **Exterior Walls**: Test for water leakage in accordance with ASTM E 2128. Unless otherwise indicated, the acceptable limit is no leakage for 15 minutes

- **Microbial Growth**: To test for support of microbial growth, test in accordance with ASTM D6329. Indicate susceptibility of product or material to colonization and amplification of microorganisms (identify microorganisms and conditions of testing). To investigate growth under “normal” conditions, perform testing at 95°F and 50 percent relative humidity. To investigate growth under “extreme” conditions, perform worst-case scenarios screening tests by providing an atmosphere where environmental conditions are deemed most favorable for microbial growth.

Moisture control during construction shall also comply with the requirements of the moisture and mold provisions of the SMACNA IAQ Guidelines for Occupied Buildings Under Construction.

11.2.3 Pre-Occupancy Flush-Out and Clearance Testing

Guiding Principle IV, Enhance Indoor Air Quality, requires that after construction and prior to occupancy, a minimum 72-hour flush-out with maximum outdoor air be conducted, consistent with achieving relative humidity no greater than 60 percent. Return air from the flush-out shall be filtered through new filter media (minimum MERV 8), and these filters shall be replaced with new filters (minimum MERV 13) prior to occupancy or re-occupancy.

If clearance testing is performed after flush-out and prior to occupancy, test protocols should be consistent with those provided in the EPA *Compendium of Methods for the Determination of Air Pollutants in Indoor Air* or other validated industrial hygiene sampling and analytical methods, including the use of direct-reading instrumentation. All testing shall be conducted during the anticipated normal occupied hours for the building. The building ventilation system should operate at its normal daily start time, at the minimum outside airflow rate for the occupied mode, for the duration of the test procedure. The building shall have all interior finishes installed, including but not limited to millwork, doors, paint, carpet, and acoustic tiles. Non-fixed furnishings such as workstations and partitions are required to be in place for the testing.

The number of air sampling locations will vary depending on the size of the building and the number of ventilation systems. For each portion of the building served by a separate ventilation system, the number of sampling locations shall not be less than one per 25,000 GSF or for each contiguous floor area (whichever is larger) and shall include areas with the least ventilation and greatest presumed source strength. At each sample location, the measurements shall be collected between 4 feet and 7 feet from the floor to represent the breathing zone of occupants. At each location, samples shall be collected over a minimum 4-hour period.

Testing results must demonstrate that contaminant concentrations do not exceed the maximum concentrations indicated in Table 11-1:

Table 11-1: Clearance Air Testing Requirements

Contaminant	Clearance Criteria
Carbon Dioxide (CO_2)*	10,300/Ventilation rate
Carbon Monoxide (CO)	9 ppm and no readings > 2 ppm above outdoor levels
Total Volatile Organic Compounds (TVOC)	< 500 µg/m^3
Formaldehyde	< 27 ppb
4-Phenylcyclohexene (4-PCH)	< 6.5 µg/m^3
Other Individual VOCs	Below odor and/or sensory irritation thresholds and < 10% of the ACGIH TLV
Total Aldehydes	< 100 ppb
Total Particles	< 50 µg/m^3

* CO_2 monitoring is required only if the building is occupied during the testing. The ventilation rate is the outdoor air requirement per person, and the CO_2 measurement is the differential between indoor and outdoor conditions, based on occupancy type as defined by ANSI/ASHRAE 62.1-2007.

ppm – parts per million; µg/m^3 – micrograms per cubic meter; ppb – parts per billion; ACGIH – American Conference of Governmental Industrial Hygienists; TLV – Threshold Limit Value; ANSI – American National Standards Institute; ASHRAE – American Society of Heating, Refrigerating, and Air Conditioning EngineersSource: GG Publications, Inc., *GREENGUARD 2005 Indoor Air Quality Guide*,Section 4.2, “Clearance and Re-occupancy Criteria,” p.28.

For each sampling location where the above maximum concentration limits are exceeded, additional flush-out using 100 percent outdoor air shall be conducted. Following the additional purging, additional readings shall be taken (at the original locations) for the specific contaminant(s) that exceeded the requirements in Table 11-1. This procedure shall be repeated until all requirements have been met.

11.2.4 Building “Tightness” Testing

Immediately prior to occupancy, the “tightness” of the building shall be evaluated using one of the following test methods:

- ASTM E779
- ASTM E1827

For commercial office buildings, the maximum leakage shall be 0.06 cubic feet per minute per square foot of exterior wall area at a pressure difference of 0.3 inches of water, exclusive of leakage through operable windows. For laboratory facilities, an alternative, site-specific leakage rate may be proposed based on operational features of the facility and its site-specific energy efficiency goals.