Mechanical Engineering

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5.1 General Requirements

This chapter identifies the mandatory criteria that shall be used to program and design mechanical systems which are defined herein as heating, ventilating and air conditioning (HVAC) systems, humidification and water treatment systems, primary heating systems, primary cooling systems, pumping and piping systems, building automation systems, and plumbing systems.

The design of the mechanical systems and other building components shall all combine together to produce a building that meets the project's programmed sustainability rating (LEED rating) and assigned energy target, as referenced in Chapter 1, *General Requirements*.

Mechanical systems must be coordinated and integrated with all other building systems and features. As addressed in Appendix A, *Submission Requirements*, mechanical systems shall be adapted to support all performance objectives, typically involving sustainability, workplace performance (productivity and efficiency), fire safety, security, historic preservation, and improved operations and maintenance.

Mechanical systems shall generally be designed to exceed the minimum performance requirements of the *ASHRAE Standard 90.1* and *10 CFR 434* standards and incorporate cost effective energy conservation measures that do not compromise building performance or occupant comfort.

Maintainability and reliability are paramount to the operation of Federal buildings. As such, the design and installation of all mechanical systems and equipment shall allow for removal and replacement, including major components such as boilers, chillers, cooling towers, pumps and air-handling equipment.

HVAC systems shall be specifically designed to function at the full load and part load conditions that are associated with the projected occupancies and modes of operations. (Special emphasis shall be placed on the design considerations for U.S. Court Facilities to allow for renovation, relocation, and creation of new Courtrooms and adjunct facilities or retrofitting Courtroom facilities for other Agencies' use. See Chapter 9, *Design Standards for U. S. Court Facilities*, for design criteria.)

HVAC systems shall be designed with standby capacity, enabling continuous service during repair or replacement of a failed piece of equipment or component. Where redundancy is required, it shall generally be accomplished by providing equipment with standby capacity rather than providing stand-alone redundant equipment.

Proposed systems and equipment using advanced technology will be considered by the GSA; however, GSA does not allow use of experimental, unproven, or proprietary equipment or systems. Documented proof of historical capability and adaptability of all equipment and systems proposed for a project shall be made available to GSA.

To facilitate design integration, the designer is encouraged to visit the Whole Building Design Guide website, **www.wbdg.org**, to identify program goal principles and to consider available technologies.

Refer to Chapter 1 for information regarding commissioning and the role of the mechanical engineer in the commissioning process.

Submission requirements are addressed in Appendix A.3.

5.2 Codes & Standards

Mechanical Codes

As stated in Chapter 1, *General Requirements, Codes and Standards, Building Codes*, facilities shall comply with the ICC's International Mechanical Code and the International Plumbing Code.

Mechanical Design Standards

The latest editions of publications and standards listed here are intended as guidelines for design. They are mandatory only where referenced as such in the text of this chapter or in applicable codes. The list is not meant to restrict the use of additional guides or standards.

When publications and standards are referenced as mandatory, any recommended practices or features shall be considered as "required." When discrepancies between requirements are encountered, GSA shall determine the requirement.

- *ASHRAE: Handbook of Fundamentals.*
  - *HVAC System Duct Design*, Chapter 34.
- *ASHRAE: Handbook of HVAC Applications.*
- *ASHRAE: Handbook of HVAC Systems and Equipment.*
- *ASHRAE: Standard 15: Safety Code for Mechanical Refrigeration.*
- *ASHRAE: Standard 52.2: Method of Testing: General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.*
- *ASHRAE: Standard 55: Thermal Environmental Conditions for Human Occupancy.*
- *ASHRAE: Standard 62: Ventilation for Acceptable Indoor Air Quality.*
- *ASHRAE: Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings.*
- *ASHRAE: Standard 100: Energy Conservation in Existing Buildings.*
- *ASHRAE: Standard 105: Standard Method of Measuring and Expressing Building Energy Performance.*
- *ASHRAE: Standard 111: Practices for Measurement, Testing, Adjusting and Balancing of Building HVAC Systems.*
- *ASHRAE: Standard 114: Energy Management Control Systems Instrumentation.*
- *ASHRAE: Standard 135: BACnet: A Data Communication Protocol for Building Automation and Control Networks.*
- *ASHRAE: Guideline #4: Preparation of Operating and Maintenance Documentation for Building Systems.*
- *ASHRAE: Guideline #12: Minimizing the Risk of Legionellosis Associated with Building Water Systems.*
- American National Standards Association: *ANSI Z 223.1.*
- *National Fuel Gas Code Standard 54.*
- American Society of Mechanical Engineers: *ASME Manuals.*
- American Society of Plumbing Engineers: *ASPE Data Books.*
- Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA):
  - *SMACNA HVAC Duct Construction Standards: Metal and Flexible.*
  - *SMACNA HVAC Air Duct Leakage Test Manual.*
  - *SMACNA Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems.*
  - *Seismic Restraint Manual Guidelines for Mechanical Systems.*
- NFPA Standard 96
- All applicable regulations and requirements of local utility companies having jurisdiction.
- EIA/TIA Standard 569: *Commercial Building Standard For Telecommunications Pathways And Spaces* (and related bulletins).

5.3 Design Criteria

Outdoor Design Criteria

Outdoor air design criteria shall be based on weather data tabulated in the latest edition of the *ASHRAE Handbook of Fundamentals*. Winter design conditions shall be based on the 99.6% column dry bulb temperature. Summer design conditions for sensible heat load calculations shall be based on the 0.4% 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% dew point with its mean coincident dry bulb temperature.

Indoor Design Criteria

Indoor Design Temperatures and Relative Humidity. Indoor design temperatures and relative humidity requirements are stated in Table 5-1.

It is necessary to maintain a relative humidity (RH) of 30 to 60% for the storage and display of artwork. In a hot and dry geographic region maintain a RH between 30 to 40%. In humid climates a range of 50 to 60% is acceptable.

Please consult Chapter 4.1, *Installation Standards*, of the *Fine Arts Program Desk Guide* for additional information.

Limitation of Supply Air Temperature. Low temperature supply air HVAC systems shall not be permitted. Supply air shall be no less than 10° C (50° F) dry bulb, in order to prevent condensation on the duct surfaces.

Building Pressurization. To keep dry air flowing through building cavities, systems shall be designed with sequence of operations that assure continuous positive pressure with respect to the outdoor environment until the outdoor dew point drops below 2.8°C (37°F), when the building pressure shall be brought to neutral. The building HVAC systems shall have an active means of measuring and maintaining this positive pressure relationship. Minimum outdoor airflow rates shall be adjusted as necessary to ensure building pressurization.

The BAS shall alarm when the building pressurization drops below a predetermined low limit. In areas where exhaust systems are used or an indoor air quality contaminant source is located, a negative pressure shall be maintained relative to surrounding spaces. Calculations shall be provided that show the minimum outdoor airflow rate required for pressurization.

The following areas shall be kept under negative pressure relative to surrounding building areas: smoking lounge, detention cells, toilets, showers, locker rooms, custodial spaces, battery charging rooms, kitchens and dining areas. Air can be returned from the dining area space. The air from all other spaces must be exhausted directly to the outdoors.

Indoor Air Quality. GSA recognizes the importance of adequate ventilation to maintain indoor air quality. The outdoor air ventilation rates of *ASHRAE Standard 62* are the minimum acceptable in GSA 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.

Air filtration shall be provided in every air-handling system. Air-handling units shall have a disposable pre-filter and a final filter. The filter media shall be rated in accordance with *ASHRAE Standard 52.2*. The pre-filters shall have a Minimum Efficiency Reporting Value (MERV) of 8 (30% - 35% efficient with a maximum

Table 5-1
Indoor Design Conditions[3]

Type of Area	Summer DB[1]	Summer RH[2]	Winter DB[1]	Winter RH[2]
General Office	24 (75)		22 (72)	
ADP Rooms[9]	22 (72)	45[4]	22 (72)	
Corridors	24 (75)		22 (72)	
Building Lobbies[10]	24 (75)		22 (72)	
Toilets	24 (75)		22 (72)	
Locker Rooms	26 (78)		21 (70)	
Electrical Closets	26 (78)		13 (55)	
Mech. Spaces	35 (95)[5]		13 (55)[8]	
Elec. Switchgear	35 (95)[5]		13 (55)	
Elevator Mach. Room[10]	26 (78)[5]		13 (55)	
Emerg. Gen. Room	40 (104)[6]		18 (65)	
Transformer Vaults	40 (104)[5]			
Stairwells	(none)		18 (65)	
Comm./Tel. Frame Room[7]	24 (75)	45	22 (72)	30[12]
Storage Room	30 (85)		18 (65)	
Conference Room[11]	24 (75)		22 (72)	
Auditorium[10]	24 (75)		22 (72)	
Kitchen[10]	24 (75)		22 (72)	
Dining[10]	24 (75)		22 (72)	
Cafeteria[10]	24 (75)		22 (72)	
Courtrooms	24 (75)		22 (72)	454*

*Requires humidification in the winter.

Notes:

1 Temperatures are degrees Celsius (Fahrenheit), to be maintained at +/-1 °C (+/-2 °F).
2 Relative humidity is minimum permissible, stated in percent. Maximum permissible relative humidity is 60 percent in conditioned areas.
3 Dry bulb and relative humidity are to be maintained 150 mm (6 inches) to 1800 mm (6 feet) above the floor.
4 Relative humidity should be maintained at +/-5 percent in ADP spaces.
5 Maximum temperature. Space to be mechanically cooled if necessary.
6 Room must not exceed temperature with generator running.
7 Must comply with EIA/TIA Standard 569.
8 Minimum temperature in the building must be 13 °C (55 °F) even when unoccupied.
9 Confirm equipment manufacturer 's requirements as more stringent. Provide in-room display and monitor device (such as wall mounted temperature and humidity chart recorder),
10 System shall be designed for process cooling. Cooling system shall be a dedicated independent system.
11 Provide independent temperature control.
12 Minimum relative humidity requirements may be omitted in moderate southern climate zones upon approval of local GSA representatives.

allowable particle size of 10.0 micron), while the final filters shall have a MERV of 13 (80% - 90% efficient with a maximum particle size of 1.0 micron). Filter racks shall be designed to minimize the bypass of air around the filter media with a maximum bypass leakage of 0.5 percent.

The placement and location of outdoor air intakes are critical to the safety of the occupants inside a building and must be in compliance with the security requirements of the building, as described in Chapter 8, *Security Design*. Table 5-2 provides a guide for minimum separation distances between ventilation air intakes and other building features.

Internal Heat Gain Design Criteria

Occupancy Levels. For office spaces, the average density of the *occupiable floor area* of a GSA building is one person per 9.3 usable m^2 (100 usable sq.ft.).Within areas occupied by workstations, the occupancy load can be as dense as one person per 7 usable m^2 (75 usable sq.ft.) in local areas. Sensible and latent loads per person shall be based on the latest edition the *ASHRAE Handbook of Fundamentals*.

For dining areas, auditoriums and other high occupancy spaces, occupancy loads shall represent the number of seats available. Areas such as storage rooms or mechanical rooms do not have occupancy loads.

Equipment Power Densities. Internal heat gain from all appliances-electrical, gas, or steam-shall be taken into account. The rates of heat gain from equipment shall be based on the latest edition of the *ASHRAE Handbook of Fundamentals* or manufacturers' data. For printers and personal computers, 80 percent diversity shall be considered.

The internal heat gains from equipment shall be coordinated with, and based on, the electrical load analysis, and the estimated receptacle demand load outlined in Chapter 6.

Lighting Power Densities. The rates of heat gain from lighting systems shall be based on the latest edition of the *ASHRAE Handbook of Fundamentals* or manufacturers' data.

The internal heat gains from lighting systems shall be coordinated with, and based on, the electrical load analysis outlined in Chapter 6.

Table 5-2
Air Intake Minimum Separation Distances

Object	Minimum Distance m	Minimum Distance ft
Property line	1	3
Garage entry, loading dock	7	25
Driveway, street or public way	3	10
Limited access highway	7	25
Grade	14	50
Roof*	0.5	1
Cooling tower or evaporative condensers	5	15
Exhaust fans and plumbing vents	3	10
Kitchen supply and exhaust air	7	25

* Roof intakes must be at least 0.2 m (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 13 mm (0.5 inch) mesh screen. The screen should be of corrosion-resistant material and located outside of or no more that 0.2 m (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 stories or less, locate the intakes on the roof or as high as possible. Locating intakes high on the exterior wall is preferred to a roof location. Outside air intake is not permitted within seven meters (twenty-five feet) of loading dock or any other fume producing areas.

Acoustical Design Criteria

All mechanical systems must be designed to satisfy the acoustical design criteria detailed in Chapter 3.

Thermostatic Zoning Design Criteria

Interior thermostatic control zones must not exceed 139 m^2 (1,500 sq.ft.) 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 28 m^2 (300 sq.ft.) and shall be no more than 4.6 m (15 ft) from an outdoor wall along a common exposure. Corner offices shall be a dedicated zone.

If a building program shows that an office building shall have an open plan layout or if the program does not state a preference, it may be assumed that up to 40 percent of the floor plan shall be occupied by closed offices at some point in the future.

Single air-handling units shall not serve multiple floors or scattered building loads. Systems designed for Federal Courthouses shall have no more than two courtrooms served by a single air-handling unit, and that air-handling unit shall be dedicated to serving only those two courtrooms.

HVAC Loads Calculations and Energy Calculations Criteria

HVAC Loads Calculations. The HVAC loads calculations shall be preformed with a computer-based program using the latest *ASHRAE Handbook of Fundamentals* Heat Balance Method (HB), Radiant time Series (RTS) Method, or Transfer Function Method (TFM), developed for the hourly analysis of heating and cooling loads in commercial buildings.

The program shall be capable of calculating each zone's peak heating and cooling load as well as the whole-building "block" loads. The program shall, at a minimum, calculate: solar gains through fenestration, internal gains from occupants including latent heat for cooling purposes, internal gains from lighting and equipment, outside air loads (sensible and latent) from ventilation and infiltration, and heat gains or losses through fenestration, walls, floors and roofs. The heating load calculations must be done without credit for occupants and internal gains.

The HVAC loads calculations report shall include all input and output used in the heating and cooling calculation program, and shall include zone peak heating and cooling loads results, and whole building "block" loads, air-handling unit coil selections, and psychrometric process charts.

Energy Calculations. A building energy analysis shall be performed to demonstrate that the building design meets or exceeds the energy performance goals established for the project. Refer to Chapter 1 for specific energy performance goals requirements.

The building energy analysis shall be performed using the *ASHRAE Standard 90.1 Energy Cost Budget* methodology, and must demonstrate compliance with the latest editions of *ASHRAE Standard 90.1*, *10 CFR 434*, and *10 CFR 435*. The analysis shall be included in each design submission as described in Appendix A.3.

The analysis shall evaluate the energy performance of the building design including the proposed building envelope, HVAC systems and components, the lighting systems, and domestic hot water systems, as well as the proposed control strategies for these building systems.

The analysis shall be based on actual parameters and values found in the proposed building design and not simply on defaults assigned by the simulation program.

The analysis shall be performed using a simulation program. The simulation program shall be a computer-based program for the analysis of energy in buildings. Simulation programs must be capable of simulating: 8,760-hours per year, hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation defined separately for each day of the week and holidays, thermal mass effects, the number of required HVAC zones, part-load performance curves for mechanical equipment, capacity and efficiency correction curves for mechanical equipment, air-side and water-side economizers, and temperature controls.

Public domain or commercial software shall utilize the EnergyPlus, DOE-2.1E, or DOE2.2 simulation engines. Alternative simulation programs, meeting the above stated requirements, may be used with prior approval of the GSA.

The building energy analysis report shall include all input and output used in the simulation programs, including: established energy goals for the project, detailed descriptions of the budget and proposed building models, actual local utility rates, descriptions of any and all energy conservation measures, an analysis of results with final conclusions and recommendations.

5.4 HVAC Baseline System

Baseline System Requirements

GSA requires the use of the HVAC baseline system described below. Any deviation from the GSA defined baseline HVAC system, or from the directives described herein, shall not be permitted unless previously identified in project programming requirements and submitted directly to, and subsequently authorized by, the GSA.

The following section describes the HVAC Baseline System and sets forth the minimum system requirements for GSA projects.

The baseline HVAC system shall be comprised of the following systems and components:

- Dedicated Outdoor Air Ventilation Systems
- Floor-by-Floor Air-Handling Units
- Perimeter and Interior Heating and Cooling Systems

A detailed description of each of the individual HVAC components is included in section 5.8 *HVAC Components*.

Dedicated Outdoor Air Ventilation Systems. The building shall have dedicated 100-percent outdoor air ventilation systems (DOAVS) sized to meet both the ventilation and pressurization requirements of the building. These physically secure, vertically zoned systems shall provide tempered dehumidified outdoor air to the occupied spaces by either of the two following methods depending on the specific application, the perimeter heating and cooling system proposed, and building configuration:

- Use a dedicated 100-percent outdoor air ventilation distribution system ducted directly to the occupied spaces, or

- Use a dedicated 100-percent outdoor air ventilation distribution system ducted through an air flow control device (air flow measuring station) to the return side of the floor-by-floor air handling units. In this case, the system shall be provided with a means of bypassing the floor-by-floor air-handling unit during unoccupied hours.

The dedicated 100-percent outdoor air ventilation systems shall be completely independent of any other air distribution system. Building exhaust air heat recovery shall be provided to precondition the outdoor air.

When determining the capacity of the dedicated 100-percent outdoor air ventilation system, the designer must consider diversity in the calculation of ventilation demand. In addition, the designer must provide building air balance calculations (including: outdoor air, supply air, return air, and exhaust air) verifying that the largest of the two DOAVS sizing requirements (ventilation or pressurization) has been met.

Supply air dew point leaving the air-handling unit shall be maintained at 10.0°C (50°F) and the supply air dry bulb temperature leaving the air-handling unit shall be a minimum of 12.8°C (55° F) and not greater than 25.6°C (78° F) during occupied hours. During occupied hours, this unit shall operate to deliver conditioned ventilation air directly to the occupied spaces to both supply the required ventilation air flow rates and to maintain positive pressure in the perimeter zones with respect to outdoor air pressure. During unoccupied hours, the DOAVS air-handling unit shall run at reduced capacity (the minimum of either 30-40% of supply capacity or as required by calculation) to provide conditioned air at 10.0°C (50° F) dew point and at least 21.1°C (70°F) to maintain positive pressure in the perimeter zones with respect to outdoor air pressure. When the outdoor air dew point drops below 2.8°C (37°F), the unit shall have the capacity to maintain neutral pressure in the perimeter zones with respect to the outdoors.

Floor-by-floor Air-Handling Units. The building shall have multiple, horizontally zoned, recirculating, Variable Air Volume (VAV) air-handling units. The air-handling units shall provide all of the required conditioning for the spaces they serve, and shall deliver conditioned supply air to the perimeter and interior heating and cooling systems. Floor-by-floor air-handling units shall utilize VAV terminals or fan-powered VAV terminals.

The VAV supply fan shall be designed for the largest block load, not the sum of the individual peaks. The air-handling unit and associated VAV terminals or fan-powered terminals shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS Direct Digital Control (DDC) Building Automated System.

All underfloor air distribution air-handling units and systems shall be designed in accordance with the *GSA PBS Guidelines for Raised Floor Systems, with and without Underfloor Air Distribution* (RF/UFAD Guidelines). Any design parameters or design criteria contained in the RF/UFAD Guidelines supersede those herein.

Perimeter and Interior Heating and Cooling Systems. Perimeter and interior zones shall have a baseline perimeter heating and cooling system selected from one of the following four options depending on the specific application and building configuration:

- Use a ducted overhead variable air volume (VAV) air distribution system with VAV terminals with hot water heating coils for cooling and heating, supplemented (where required) with hot water finned-tube radiation, or

- Use a ducted overhead variable air volume (VAV) air distribution system with fan-powered VAV terminals with hot water heating coils for cooling and heating, or
- Use an underfloor VAV air distribution (UFAD/VAV) system designed in accordance with the RF/UFAD Guidelines for cooling, supplemented with two-pipe, above floor perimeter hot water finned-tube radiation for heating, or
- Use a standard, floor mounted four-pipe fan coil unit system for heating and cooling for perimeter zones. Interior zones must be served by one of the previous three VAV system options. Ceiling mounted fan coil units are not permitted.

Electric heating coils shall be permitted only for nominal heating requirements. Requests for use of electric heating coils must be submitted directly to, and subsequently authorized by, the GSA. No reheat is permitted.

5.5 Alternatives Components for the HVAC Baseline System

Life Cycle Costing of Alternatives

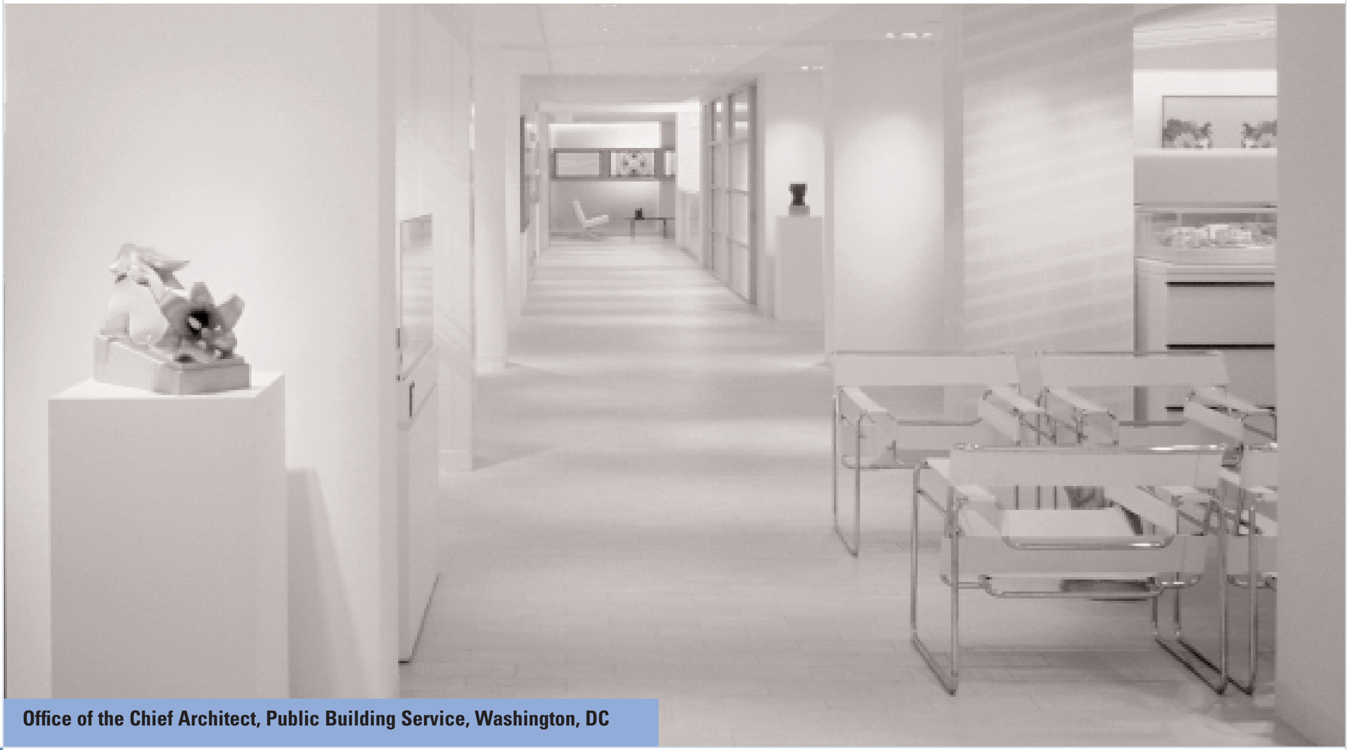
A life cycle cost analysis shall be performed to determine the applicability and economic justification of the following alternatives for each project.

Life cycle cost analysis shall comply with requirements addressed in Chapter 1, *General Requirements*. This includes consideration of analysis period, escalation discount rates, and other parameters. The indicated software program, "Buildings Life Cycle Cost", is recommended when used with provisions that support "Federal Analysis-Projects Subpart to OMB A-94 Guidelines."

The building energy analysis shall be used to predict the energy cost impact of each of the alternative outdoor air distribution methods and components, as compared to the baseline HVAC system, and shall form the basis of the life cycle cost analysis.

- **Alternative Outdoor Air Distribution Method – Dedicated Perimeter Pressurization System.** For projects where a dedicated 100-percent outdoor air ventilation system, sized to meet both the ventilation and pressurization requirements of the building, is deemed to be infeasible by GSA (supported by a life cycle cost analysis provided by the A/E), the building shall have a dedicated perimeter pressurization system sized to meet only the pressurization requirements of the building. In these cases, the ventilation requirements of the building shall be provided by the floor-by-floor air-handling units. This exception to the dedicated 100-percent outdoor air ventilation system requirement is limited to special applications or modernization projects where the DOAVS approach is infeasible.

- **Alternative Component – Desiccant Cooling.** Desiccant cooling with a solid silica gel desiccant may be used in combination with mechanical cooling for high occupancy applications where moisture removal is required. Natural gas or condenser waste heat shall be used as fuel for reactivation of the desiccant. Lithium chloride liquid desiccants are not permitted. Where these conditions are satisfied, the A/E shall analyze the life cycle cost of this option.
- **Alternative Component – Economizer Cycles.** For floor-by-floor air-handling units with capacities over 1,416 L/s (3,000 cfm), the A/E shall analyze the life cycle cost of providing a full air-side economizer cycle capable of providing full free cooling, or partial air-side economizer cycle capable of providing some free cooling, and used in conjunction with additional mechanical cooling. The designer must ensure that proposed locations of outdoor air intakes meet the GSA security requirements prior to performing the life cycle cost analysis. If secure outdoor air intakes are not feasible for this alternative, then the alternative shall not be considered. The air-side economizer cycle shall provide leaving air conditions at a maximum of 10.0°C (50°F) dew point and a maximum of 70 percent relative humidity. Where an air-side economizer is not justified on a life-cycle cost basis, the A/E shall analyze the life cycle cost of providing a water-side economizer cycle.



Office of the Chief Architect, Public Building Service, Washington, DC

5.6 Special Area HVAC Systems

Special Area Requirements

Special areas such as atriums, cafeterias, mail rooms, loading docks and elevator machine rooms, shall have a dedicated air-handling unit, separate from all other air-handling units in the building, with individual control to condition these spaces as required.

Lobbies and Entrance Vestibules. A dedicated air-handling unit shall be provided for the main lobby and other entrance vestibules to maintain positive pressurization.

Courtrooms. Generally, each Courtroom and its respective ancillary areas coupled to the operation of the Courtroom shall constitute a primary zone. No more than two Courtrooms and their respective ancillary areas shall be supplied from the same air-handling unit and system. Refer to the U.S. Courts Design Guide published by the Administrative Office of the United States Courts (AOC) for specific requirements.

Auditoriums. Auditoriums shall have dedicated air-handling units. Units shall be designed with 80 percent diversity factor to maintain necessary temperature and humidity conditions under partial loads and partial occupancy. Provide dew point control. Dew point of supply air shall not exceed 10.0°C (50°F) dry bulb.

U.S. Marshals Service Areas. The U.S. Marshals Service area HVAC system shall be designed for continuous operation and shall be independently controlled and zoned. All ductwork and air circulation openings penetrating the secure area envelope, including prisoner circulation areas, shall be provided with security bars. Detainee holding areas shall be negatively pressurized with regard to adjacent spaces and exhausted directly to the outdoors. Refer also to requirements of U.S. Marshals Service (USMS) Publication 64.

Firing Range. Special HVAC considerations shall be required for firing ranges. A firing range shall be provided with a dedicated air-handling system. Heating and cooling supply air shall be delivered to the area along and behind the firing line for occupant comfort conditions and to maintain a positive pressure in this area relative to down range and target area. Powered exhaust air shall be extracted from down range and the target areas in sufficient quantity to remove smoke and maintain a clear line of vision to the target. Sixty percent of the total exhaust shall be extracted at a point approximately one-third the distance from the firing line to the target area, and forty percent shall be extracted from above the target area. All exhaust air shall be filtered to preclude the emission of lead particulates and gunpowder residue into the atmosphere. Discharge of firing range exhaust air to outdoors shall be carefully located to prevent recirculation into the outdoor air intake of any HVAC system. Firing range systems shall be capable of continuous operation, isolated from other building systems.

Kitchens and Dishwashing Areas. Kitchens with cooking ranges, steam kettles, ovens and dishwashers shall be provided with dedicated make-up air and exhaust hoods/exhaust systems in accordance with the latest edition of NFPA Standard 96 and *ASHRAE Applications Handbook*. All components of the ventilation system shall be designed to operate in balance with each other, even under variable loads, to properly capture, contain, and remove the cooking effluent and heat, and maintain proper temperature and pressurization control in the spaces in an efficient and economic manner. The operation of the kitchen exhaust systems shall not affect the pressure relation between the kitchen and surrounding spaces. Both supply air and makeup air shall be exhausted through the kitchen hood heat recovery system while a maximum of 30 percent of the exhaust air is made up from the space.

Floor drains must be provided at each item of kitchen equipment where accidental spillage can be anticipated, and to facilitate floor-cleaning procedures. Drains to receive indirect wastes for equipment shall be of the floor sink type of stainless construction with a sediment bucket and removable grate.

Areas of Refuge. The area of refuge provided for the Judiciary in the event of emergency conditions shall be provided with adequate ventilation energized from the emergency power distribution system and sufficient heating capacity to maintain space temperature of 21.1°C (70°F) with design winter outdoor temperature. Provide separate air-handling unit to maintain positive pressure, relative to surrounding spaces, with heating-cooling coils and differential pressure sensing system.

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24-Hour Spaces. All areas designated as requiring 24-hour operations shall be provided with a dedicated and independent HVAC system. All spaces handling BAS computer processing of Fire Alarm Monitor and Control Systems, Security Monitor and Control Systems and/or energy monitoring and control systems shall be provided with dedicated HVAC systems to maintain temperature, humidity and ventilation requirements at all times. Twenty-four hour systems shall have dedicated chiller(s), cooling tower(s) boiler(s), and associated pumping systems. However, central system(s) can be used to provide chilled water and hot water during the normal operating hours, or as a backup for the 24-hour system(s). Twenty-four hour systems with a cooling capacity of up to 176 kW (50 tons) shall be configured with an air-cooled chiller. In the event the building's 24-hour operation load, including the dedicated perimeter ventilation system, exceeds 176 kW (50 tons), the cooling systems may be combined with a central system in which a dedicated central chilled water supply loop shall be provided along with 24-hour chiller.

Computer Rooms. Computer rooms shall be cooled by self-contained units for cooling loads up to 281 kW (80 tons). These units shall be specifically designed for this purpose and contain compressors, filters, humidifiers and controls. They shall be sized to allow for a minimum of 50 percent redundancy, either two units at 75 percent load or three units at 50 percent. If the nature of the computer room is critical (as determined by consulting the GSA's Office of the Chief Information Officer), three units sized at 50 percent of the design load shall be used. Heat rejection from these self-contained units shall be by air-cooled condensers or recirculating water-cooled condensers connected to a cooling tower or evaporative-cooled condenser. Water-side free cooling shall be utilized when possible.

For cooling loads greater than 281 kW (80 tons), chilled water air-handling systems shall be considered in a life cycle cost analysis. A dedicated chiller(s) is preferred, unless other parts of the building also require 24-hour cooling. The dedicated chiller plant shall provide some means of redundant backup, either by multiple machines or connection to the facility's larger chilled water plant.

In large computer installations [areas of 465 m^2 (5,000 sq. ft.)] it is recommended to segregate cooling of the sensible load (computer load) and control of the outdoor air ventilation and space relative humidity by using two separate air-handling systems. In this design, one unit recirculates and cools room air without dehumidification capability. This unit is regulated by a room thermostat. The second unit handles the outdoor air load, provides the required number of air changes and humidifies/ dehumidifies in response to a humidistat. This scheme avoids the common problem of simultaneously humidifying and dehumidifying the air.

These systems shall be provided with an alternative power source, connected to emergency generators, if the computer room houses critical components. Consult GSA's Office of the Chief Information Officer to determine which computer rooms meet this requirement.

Vehicle Garages. Vehicle garage exhaust fans shall generally be activated based upon carbon monoxide sensors within the garage. Carbon monoxide sensors shall also be located in all floor areas where vertical shafts penetrate the garage areas.

5.7 Mechanical and Service Space Requirements

A minimum of 4 percent of each floor's gross floor area shall be provided on that floor for air-handling equipment. Where additional equipment is required, additional space on that floor shall be provided as needed. A minimum of 1 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). All mechanical equipment rooms shall be a minimum of 3.7m (12 ft.) in height. Space requirements of mechanical and electrical equipment rooms shall be based upon the layout of required equipment drawn to scale within each room.

Service Access. Space 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 in ventilation equipment, ductwork and plenums as required for in-site inspection and cleaning. Equipment access doors or panels shall be readily operable and sized to allow full access. Large central equipment shall be situated to facilitate its replacement. The HVAC design engineer shall be cognizant of the necessity to provide for the replacement of major equipment over the life of the building and shall insure that provisions are made to remove and replace, without damage to the structure, the largest and heaviest component that cannot be further broken down.

In addition, adequate methods of access shall be included for items such as: chillers, boilers, air-handling units, heat exchangers, cooling towers, reheat coils, VAV terminals, pumps, water heaters and all devices that have maintenance service requirements.

To facilitate equipment access, maintenance, removal and replacement, a freight elevator stop shall be provided to serve each floor housing HVAC systems and equipment.

Where stairs are required, they must allow for safe transport of equipment and components. Ship's ladders are not permitted for access and maintenance of any equipment.

Vertical Clearances. Mechanical equipment rooms shall have clear ceiling heights of not less than 3.7 m (12 ft). Catwalks with stairways shall be provided for all equipment that cannot be maintained from floor level. Where maintenance requires the lifting of heavy parts [45 kg (100 lb) or more], hoists and hatchways shall be installed.

Horizontal Clearances. Mechanical rooms shall be configured with clear circulation aisles and adequate access to all equipment. The arrangement shall consider the future removal and replacement of all equipment. The mechanical rooms 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 (noted by outlining manufacturer's recommendations) for maintenance and removal of coils, filters, motors, and similar devices shall be provided. Chillers shall be placed to permit pulling of tubes from all units. The clearance shall equal the length of the tubes plus 610 mm (2 ft). Air-handling units require a minimum clearance of 762 mm (2 ft 6 in) on all sides, except the sides that filters and coils are accessed, where clearance shall be equal to the length of the coils plus 610 mm (2 ft).

Roof-Mounted Equipment. No mechanical equipment except for cooling towers, air-cooled chillers, evaporative condensers, and exhaust fans shall be permitted on the roof of the building. Access to roof-mounted equipment shall be by stairs, not by ship's ladders.

Housekeeping Pads. Housekeeping pads shall be at least 152 mm (6 in) wider on all sides than the equipment they support and shall be 152 mm (6 in) thick.

Mechanical Rooms. All mechanical rooms must be mechanically ventilated to maintain room space conditions as indicated in *ASHRAE 62, ASHRAE 15*, and Table 5-1 of this chapter. Water lines shall not be located above motor control centers or disconnect switches and shall comply with 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. Mechanical rooms shall not be used as return air, outdoor air, or mixing plenums. Mechanical equipment rooms must be designed in accordance with the requirements of *ASHRAE Standard 15: Safety Code for Mechanical Refrigeration*.

Chiller Equipment Rooms. All rooms for refrigerant units shall be constructed and equipped to comply with *ASHRAE Standard 15: Safety Code for Mechanical Refrigeration*. Chiller staging controls shall be capable of DDC communication to the central building Energy Management System.

Electrical Equipment Rooms. No water lines are permitted in electrical rooms, except for fire sprinkler piping. Sprinkler piping lines must not be located directly above any electrical equipment.

Communications Closets. Communications closets must be cooled in accordance with the requirements of EIA/TIA Standard 569. Closets which house critical communications components shall be provided with dedicated air-conditioning systems that shall be connected to the emergency power distribution system.

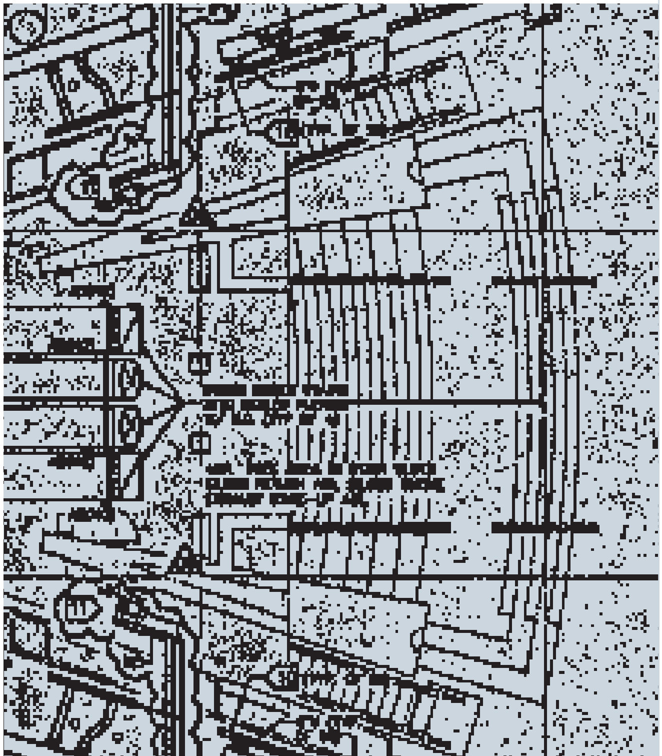
Elevator Machine Rooms. A dedicated heating and/or cooling system must be provided to maintain room mechanical conditions required by equipment specifications, and in accordance with Table 5-1 of this chapter.

In the event the building is equipped throughout with automatic sprinklers, hoist way venting is not required.

Emergency Generator Rooms. The environmental systems shall meet the requirements of NFPA Standard 110: *Emergency and Standby Power Systems* and meet the combustion air requirements of the equipment. Rooms must be ventilated sufficiently to remove heat gain from equipment operation. The supply and exhaust louvers shall be located to prevent short circuiting. Generator exhaust shall be carried up to roof level (GSA preference) in a flue or exhausted by way of compliance with the generator manufacturer's installation guidelines. Horizontal exhaust through the building wall shall be avoided.

UPS Battery Rooms. Battery rooms must be equipped with emergency eyewash and shower equipment (ANSI Standard Z358.1). Floor drains required at the emergency shower, within the battery room acid containment curb, shall extend with acid waste piping to an acid neutralization tank prior to discharge to the sanitary sewer or building drain. The battery room must be ventilated/exhausted directly to the outdoors at a rate calculated to be in compliance with code requirements and manufacturer's recommendations, and the exhaust system must be connected to the emergency power distribution system. Fans shall be spark-resistant, explosion proof, with motor outdoor the air stream, ductwork to be negative pressure system of corrosion-resistant material, with exhaust directly to outdoors in a dedicated system. Acoustical enclosures shall be provided to maintain a maximum NC level of 35. Coordinate with electrical design specifications to include HVAC support equipment in UPS extended servicing agreements.

Loading Docks. The entrances and exits at loading docks and service entrances shall be maintained at negative pressure relative to the rest of the building with a means to reduce infiltration and outdoor debris.



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5.8 HVAC Components

Air-Handling Units (AHU). All air-handling units, including dedicated outdoor air ventilation units, dedicated perimeter pressurization units, floor-by-floor air-handling units, and air-handling units serving special areas, shall be sized to not exceed 11,800 L/s (25,000 cfm).

Smaller units are encouraged to facilitate flexible zone control, particularly for spaces that involve off-hour or high-load operating conditions. To the extent possible, "plug-n-play" AHU configurations shall be considered, facilitating easy future adaptations to space-load changes.

Psychrometric process charts shall be prepared for each air-handling unit application, characterizing full and part load operating conditions. Air-handling unit/coil designs shall assure that conditioned space temperatures and humidity levels are within an acceptable range, per programmed requirements, Table 5.1, and *ASHRAE Standard 62*.

Depending on sensible heat ratio characteristics, effective moisture control may require cooling coil air discharge dew point temperatures as low as 10.0°C (50°F). As required, provide face-by-pass or heat recovery features to re-heat cooling coil discharge temperatures for acceptable space entry. Provide a direct form of re-heat and/or humidification only if space conditions require tight environmental control, or if recurring day-long periods of unacceptable humidity levels would otherwise result.

Particular attention shall be given to the volume control. Zone loads must be calculated accurately to avoid excessive throttling of air flow due to oversized fans and terminal units. Diffusers shall be high entrainment type (3:1 minimum) to maximize air velocity at low flow rates.

If ventilation air is delivered through the VAV terminal, the minimum volume setting of the VAV terminal shall equal the larger of the following:

- Use 30 percent of the peak supply volume, or
- Use 2 L/s per m^2 (0.4 cfm/sq.ft.) of conditioned zone area, or
- Use a minimum outdoor airflow to satisfy *ASHRAE Standard 62* ventilation requirements.

Supply, Return and Relief Air Fans: Centrifugal double-width double-inlet forward curved and airfoil fans are preferable for VAV AHUs. All fans shall bear the AMCA seal and performance shall be based on tests made in accordance with AMCA Standard 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 for a 1.5 service factor and fan shafts shall be selected to operate below the first critical speed. Thrust arrestors shall be designed for horizontal discharge fans operating at high static pressure.

Coils: Individual finned tube coils shall generally be between six and eight rows with at least 2.1 mm between fins (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. All hot water heating and chilled water cooling coils shall be copper tube and copper finned materials. 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 the water droplet carryover. Cooling coils shall be selected at or below 2.5 m/s (500 fpm) face velocity to minimize moisture carryover. Heating coils shall be selected at or below 3.8 m/s (750 fpm) face velocity.

Drains and Drain Pans: Drain pans shall be made of stainless steel, insulated and adequately sloped and trapped to assure 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 25 mm (1 inch) minimum.

Filter Sections: Filters shall be sized at 2.5 m/s (500 fpm) maximum face velocity. Filter media shall be fabricated so that fibrous shedding does not exceed levels prescribed by *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, not 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 quick and accurate assessment of filter dust loading as reflected by air-pressure loss through the filter, and sensors shall be connected to building automation system.

UVC Emitters/Lamps: Ultraviolet light (C band) emitters/lamps shall be incorporated downstream of all cooling coils in an air-handling unit, and above all drain pans to control airborne and surface microbial growth and transfer. Applied fixtures/lamps must be specifically manufactured for this purpose. Safety interlocks/features shall be provided to limit hazard to operating staff.

Access Doors: Access doors shall be provided at air-handling units downstream of each coil, upstream of each filter section and adjacent to each drain pan and fan section. Access doors shall be of sufficient size to allow personnel to enter the unit to inspect and service all portions of the equipment components.

Plenum Boxes: Air-handling units shall be provided with plenum boxes where relief air is discharged from the air-handling unit. Plenum boxes may also be used on the return side of the unit in lieu of a mixing box. Air-flow control dampers shall be mounted on the ductwork connecting to the plenum box.

Mixing Boxes: Air-handling units shall be provided with mixing boxes where relief air is discharged from the air-handling unit. Mixing boxes may also be used on the return side of the unit in lieu of a plenum box. Air flow control dampers shall be mounted within the mixing box or on the ductwork connecting to the mixing box.

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 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 a VAV box/terminal shall not exceed 2% of its rated capacity. Units shall have BACnet or LONWORKS self-contained controls.

Fan-powered terminals: Fan-powered terminals shall have ECM motors for speed control to allow continuous fan speed adjustment from maximum to minimum, as a means of setting the fan airflow. Units shall have BACnet or LONWORKS self-contained controls.

Fan-powered terminals shall be equipped with a ducted return, featuring a filter/filter rack assembly with the filters having a Minimum Efficiency Reporting Value (MERV) of 10 (60% - 65% efficient with a maximum allowable particle size of 1.0 micron) and covered on all external exposed sides with two inches of insulation.

The return plenum box for fan-powered terminals shall be a minimum of 610 mm (24 in) in length and shall be double wall 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. Fan-powered terminals located on the perimeter zones and on the top floor of the building shall contain hot water coils for heating.

Air Distribution. Ductwork shall be designed in accordance with *ASHRAE: Handbook of Fundamentals, Duct Design Chapter*, and constructed in accordance with the *ASHRAE: HVAC Systems and Equipment Handbook, Duct Construction Chapter,* and the *SMACNA Design Manuals*. 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 747 Pa (3.0 in WG). In systems from 747 Pa (3.0 in WG) through 2,488 Pa (10.0 in WG) 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.

Ductwork Pressure: Table 5-3 provides pressure classification and maximum air velocities for all ductwork.

Ductwork construction shall be tested for leakage prior to installation. Each section tested must have a minimum of a 6.1 m (20 ft) length straight-run, a minimum of two elbows and a connection to the terminal. The stated static pressures represent the pressure exerted on the duct system and not the total static pressure developed by the supply fan. The actual design air velocity shall consider the recommended duct velocities in Table 5-4 when noise generation is a controlling factor. Primary air ductwork (fan connections, risers, main distribution ducts) shall be

Table 5-3
Ductwork Classification

Static Pressure		Air Velocity		Duct Class
250 Pa	(1.0 in W.G.)	< 10 m/s DN	< (2000 FPM DN)	Low Pressure
500 Pa	(2.0 in W.G)	< 10 m/s DN	< (2000 FPM DN)	Low Pressure
750 Pa	(3.0 in W.G.)	< 12.5 m/s DN	< (2500 FPM DN)	Medium Pressure
1000 Pa	(+4.0 in W.G.)	< 10 m/s DN	> (2000 FPM UP)	Medium Pressure
1500 Pa	(+6.0 in W.G.)	< 10 m/s DN	> (2000 FPM UP)	Medium Pressure
2500 Pa	(+10.0 in W.G.)	< 10 m/s DN	> (2000 FPM UP)	High Pressure

medium pressure classification as a minimum. Secondary air ductwork (runouts/branches from main to terminal terminals and distribution devices) shall be low pressure classification as a minimum.

Pressure loss in ductwork shall be designed to comply with the criteria stated above. This can 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 have to be used, double foil sound attenuating turning vanes shall be provided. Mitered elbows are not permitted where duct velocity exceeds 10.2 m/s (2,000 fpm).

Sizing of Ductwork: Supply and return ductwork shall be sized using the equal friction method except for ductwork upstream of VAV terminals. Duct systems designed using the equal friction method place enough static pressure capacity in the supply and return fans to compensate for improper field installation and changes made to the system layout in the future. In buildings with large areas of open plan space, the main duct size shall be increased for revisions in the future. Air flow diversity shall also be a sizing criterion. Eighty percent diversity can be taken at the air-handling unit 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.

Ductwork Construction: Ductwork shall be fabricated from galvanized steel, aluminum or stainless steel sheet metal depending on applications. 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. Flex duct runs shall not exceed 3.0 m (10 ft) nor 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.

Table 5-4
Recommended Duct Velocities

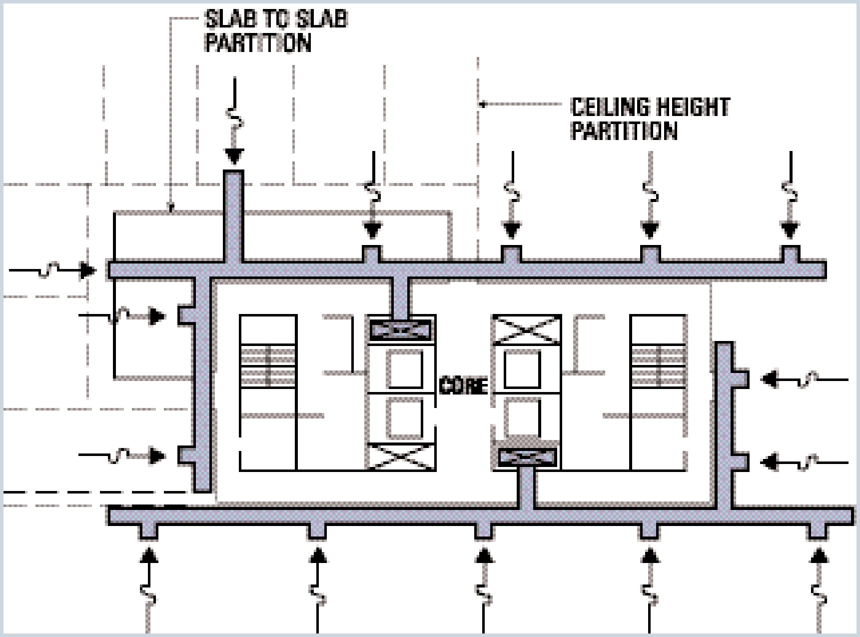
Application	Controlling Factor Noise Generation (Main Duct Velocities) m/s	(fpm)
Private Offices Conference Rooms Libraries	6	(1,200)
Theaters Auditoriums	4	(800)
General Offices	7.5	(1,500)
Cafeterias	9	(1,800)

Air Delivery Devices: Terminal ceiling diffusers or booted-plenum slots shall be specifically designed for VAV air distribution. Booted plenum slots shall not exceed 1.2 m (4 ft) 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 where the system is expected to operate most of the time. The designer shall consider the expected variation in range in the outlet air volume to ensure the air diffusion performance index (ADPI) values remain above a specified minimum. This is achieved by low temperature variation, effective air mixing, and no objectionable drafts in the occupied space, typically 152 mm (6 in) to 1,830 mm (6 ft) above the floor. Adequate ventilation requires that the selected diffusers effectively mix the total air in the room with the supplied conditioned air, which is assumed to contain adequate ventilation air.

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 air-handling unit. The horizontal distance from the farthest point in the plenum to a return duct shall not exceed 15.2 m (50 ft). No more than 944 L/s (2,000 cfm) shall be collected at any one return grille. Figure 5-1 illustrates an example of an open ceiling plenum with return air ductwork. 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, consider placing returns low in walls or on columns to complement ceiling supply air.

Figure 5-1 Ceiling Return Plenum with Minimal Return Ductwork



Return air ducts in the ceiling plenum of the floor below the roof shall be insulated. Sound attenuator shall be provided, as needed, to connect the return ductwork to the return fan or air-handling unit, in order to minimize noise and vibration.

Fan Coil Units. For perimeter spaces, provide four-pipe fan coil units with cooling coil, heating coil, MERV 10 filters, internal condensate drain, and overflow drain. Unit shall have self-contained microprocessor controls and shall be capable of connecting to and interoperating with a BACnet or LONWORKS Direct Digital Control (DDC) Building Automation System. Fan coil units shall be capable of operating with unit- mounted or remote-mounted temperature sensor. Installation of fan coil units above ceiling is not permitted.

Finned-tube Radiation. Finned-tube radiation shall have individual zone thermostatic control capable of connecting to a self-contained microprocessor that can interface with a BACnet or LONWORKS Direct Digital Control (DCC) Building Automation System.

Heat Recovery Equipment. Heat recovery equipment shall operate at a minimum of 70 percent efficiency. The heat recovery equipment must be capable of connecting to a microprocessor controller that in turn can be connected to a direct digital control (DDC) Building Automation System. Pre-filters shall be provided in all heat recovery equipment.

Heat Pipe: For sensible heat recovery a run-around type heat pipe shall use refrigerant to absorb heat from the air stream at the air intake and reject the heat back into the air stream at the discharge of the air-handling unit. System shall have solenoid valve control to operate under partial load conditions.

Run-around Coil: A glycol run-around coil may be used with control valves and a pump for part load conditions. The run-around coils shall be used at the exhaust discharge from the building and at the fresh air intake into the building. The run-around coil system shall be capable of connecting to a microprocessor controller that in turn can be connected to a direct digital control (DDC) Building Automation system.

Enthalpy Wheels: A desiccant-impregnated enthalpy wheel with variable speed rotary wheel may be used in the supply and exhaust systems.

Sensible Heat Recovery: For sensible heat recovery, a cross-flow, air-to-air (z-duct) heat exchanger shall recover the heat in the exhaust and supply air streams. Z-ducts shall be constructed entirely of sheet metal. Heat-wheels may also be used for sensible heat recovery. Unit shall have variable speed drive for controlling the temperature leaving the unit.

Kitchen Ventilation Equipment. Products of combustion from kitchen cooking equipment and appliances shall be delivered outdoor of building through the use of kitchen ventilation systems involving exhaust hoods, grease ducts and make-up air systems where required. Commercial kitchen equipment applications shall be served by a Type I hood constructed in compliance with UL 710 and designed in accordance with code having jurisdiction. Grease ducts shall be constructed of black steel not less than 1.4 mm (0.055 in, No. 16 gauge) in thickness or stainless steel not less than 1.1 mm (0.044 in, No. 18 gauge) in thickness. Make-up air systems serving kitchen exhaust hoods shall incorporate air-side heat exchange to recover energy from the exhaust stream to be used for heating the supply air stream.

Motors. All motors shall have premium efficiency as per *ASHRAE Standard 90.1*. Motors that are 0.37 kW (½ hp) and larger shall be polyphase. Motors smaller than 0.37 kW (½ hp) shall be single phase. For motors operated with variable speed drives, provide insulation cooling characteristics as per NFPA.

5.9 Humidification and Water Treatment

Make-up water for direct evaporation humidifiers shall originate directly from a potable source that has equal or better water quality with respect to both chemical and microbial contaminants. Humidifiers shall be designed so that microbiocidal chemicals and water treatment additives are not emitted in ventilation air. All components of humidification equipment shall be stainless steel. Air washer systems are not permitted for cooling.

Humidification shall be limited to building areas requiring special conditions. Courtrooms with wall coverings of wood shall be provided with humidification. 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. To avoid the potential for oversaturation and condensation at low load, the total humidification load shall be divided between multiple, independently-modulated units. Single-unit humidifiers are not acceptable.

When steam is required during summer seasons for humidification or sterilization, a separate clean steam generator shall be provided and sized for the seasonal load. Humidifiers shall be centered on the air stream to prevent stratification of the moist air. All associated equipment and piping shall be stainless steel.

The humidification system shall have BACnet or LONWORKS self-contained controls.

Water Treatment. The water treatment for all hydronic systems, including humidification systems, shall be designed by a qualified specialist. The design system shall address the three aspects of water treatment: biological growth, dissolved solids and scaling, and corrosion protection. The performance of the water treatment systems shall produce, as a minimum, the following characteristics; hardness: 0.00; iron content: 0.00; dissolved solids: 1,500 to 1,750 ppm; silica: 610 ppm or less; and a PH of 10.5 or above. The system shall operate with an injection pump transferring chemicals from solution tank(s) as required to maintain the conditions described. The chemical feed system shall have BACnet or LONWORKS self-contained controls.

The methods used to treat the systems' make-up water shall have prior success in existing facilities on the same municipal water supply and follow the guidelines outlined in *ASHRAE Applications Handbook*.

5.10 Primary Heating Systems

GSA prefers low-temperature hot-water heating systems; 207 kPa (30 psi) working pressure and maximum temperature limitation of 93.3°C (200°F). Supply temperatures and the corresponding temperature drops for space heating hot water systems must be set to best suit the equipment being served. Total system temperature drop shall not exceed 16.7°C (30°F). The temperature drop for terminal unit heating coils shall be 11.1°C (20°F). Design water velocity in piping shall not exceed 2.4 m/s (8 fps) or design pressure friction loss in piping systems shall not exceed 0.4 kPa/m (4 ft per 100 ft), whichever is larger, and not less than 1.2 m/s (4 fps).

District Steam Heating

GSA buildings are built for the long-term; therefore, it is prudent for GSA to provide the building heating system. 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 GSA to install boilers and associated equipment at a later date. 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. If steam heating is used, the designer shall investigate the use of district steam condensate for pre-heating of domestic hot water. Steam heating is not permitted inside the building other than conversion of steam-to-hot water in the mechanical room.

Also, the use of steam for HVAC applications shall be limited to the conversion of steam heat to hot water heat and for use in providing humidification. Steam shall not be used as a heating medium for distribution throughout a building to terminal units, air-handling units, perimeter heating units, coils, or any other form of heat transfer where steam is converted to a source of heat for use in space comfort control or environmental temperature control.

Steam delivered from any source other than a clean steam generation system shall be prohibited from use in providing humidification. 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.

Hot Water Heating Systems

The use of electric resistance and/or electric boilers as the primary heating source for the building is prohibited. Design and layout of hydronic heating systems shall follow the principles outlined in the latest edition of the *ASHRAE Systems and Equipment Handbook*.

Boilers. Boilers for hydronic hot water heating applications shall be dual fuel (natural gas and No. 2 fuel oil) low pressure, with a working pressure and maximum temperature limitation as previously stated, and shall be installed in a dedicated mechanical room with all provisions made for breaching, flue stack and combustion air. For northern climates, a minimum of three equally sized units shall be provided. Each of the three units shall have equal capacities such that the combined capacity of the three boilers shall satisfy 120 percent of the total peak load of heating and humidification requirements. For southern climates, a minimum of two equally sized units at 60 percent of the peak capacity (each) shall be provided. The units shall be packaged, with all components and controls factory preassembled. Controls and relief valves to limit pressure and temperature must be specified separately. Burner control shall be return water temperature actuated, and control sequences, such as modulating burner control and outdoor air reset, shall be utilized to maximum efficiency and performance. Multiple closet type condensing boilers shall be utilized, if possible. Boilers shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS Direct Digital Control (DDC) Building Automated System. Boilers shall have a minimum efficiency of 80 percent as per *ASHRAE Standard 90.1*.

Individual boilers with ratings higher than 29 MW (99 million Btu/hour) or boiler plants with ratings higher than 75 MW (256 million Btu/hour) are subject to review by the Environmental Protection Agency.

Boilers shall be piped to a common heating water header with provisions to sequence boilers on-line to match the load requirements. All units shall have adequate valving to provide isolation of off-line units without interruption of service. All required auxiliaries for the boiler systems shall be provided with expansion tanks, heat exchangers, water treatment and air separators, as required.

Gas Trains: Boiler gas trains shall be in accordance with International Risk Insurance (IRI) standards.

Automatic Valve Actuators: Gas valve actuators shall not contain NaK (sodium-potassium) elements since these pose a danger to maintenance personnel.

Venting: Products of combustion from fuel-fired appliances and equipment shall be delivered outdoor of the building through the use of breaching, vent, stack and chimney systems. breaching connecting fuel-fired equipment to vents, stacks and chimneys shall generally be horizontal and shall comply with NFPA 54. Vents, stacks and chimneys shall generally be vertical and shall comply with NFPA 54 and 211. breaching, vent, stack, and chimney systems may operate under negative, neutral, or positive pressure and shall be designed relative to the flue gas temperature and dew point, length and configuration of the system, and the value of the insulation techniques applied to the vent. Venting materials may be factory fabricated and assembled in the field and may be double or single wall systems depending on the distance from adjacent combustible or noncombustible materials. Material types, ratings and distances to adjacent building materials shall comply with NFPA 54 and 211.

Hot Water Pumps. Pumps shall be of a centrifugal type and shall generally be selected to operate at 1750 RPM. Both partial load and full load must fall on the pump curve. The number of primary hot water pumps shall correspond to the number of boilers, and a stand-by 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). The specified pump motors shall not overload throughout the entire range of the pump curve. Each boiler group pumps shall be arranged with piping, valves, and controls to allow each boiler group to operate independently of the other boiler groups.

Freeze Protection. Propylene glycol manufactured specifically for HVAC systems shall be used to protect hot water systems from freezing, where extensive runs

College Park, MD

of piping are exposed to weather, where heating operations are intermittent or where coils are exposed to large volumes of outdoor air. Freeze protection circulation pump shall be provided along with polypropylene glycol. Heat tracing systems are not acceptable for systems inside the building. Glycol solutions shall not be used directly in boilers, because of corrosion caused by the chemical breakdown of the glycol. The water make-up line for glycol systems shall be provided with an in-line water meter to monitor and maintain the proper percentage of glycol in the system. Provisions shall be made for drain down, storage and re-injection of the glycol into the system.

Radiant Heat. Radiant heating systems (hot water or gas fired) may be overhead or underfloor 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.

Natural Gas Piping. Refer to *Plumbing Systems, Natural Gas Systems* section of this chapter.

Fuel Oil Piping. Refer to *Plumbing Systems, Fuel Oil Systems* section of this chapter.

Underground Fuel Oil. *Refer to Plumbing Systems, Fuel Oil Systems* section of this chapter.

5.11 Primary Cooling Systems

The primary cooling system includes chillers, chilled water and condenser water pumps, cooling towers, piping and piping specialties. The chilled water systems shall have a temperature differential between 5.5°C and 6.7°C (10°F and 12°F) for HVAC systems that primarily use fan coil units. For HVAC systems that primarily use air-handling units, the temperature differential shall be between 6.7°C and 8.9°C (12°F and 16°F). The chilled water system shall have a design supply water temperature between 4.4°C and 7.2°C (40°F and 45°F). In climates with low relative humidity, a 7.8°C (46°F) may be used.

District Chilled Water

GSA buildings are built for the long-term; therefore, it is prudent for GSA to provide the building chilled water system. District chilled water, if available, may be considered for cooling only if it is determined to have long-term reliability and can be economically justified through a life cycle cost analysis. In the event District chilled water is utilized, appropriate space must be provided to allow GSA to install chillers, cooling towers, and associated equipment, at a later date. If chilled water is furnished to the building, such as under a district chilled water plan, it shall be used in conjunction with a heat exchanger in the mechanical room near the entrance into the building.

Chilled Water Systems

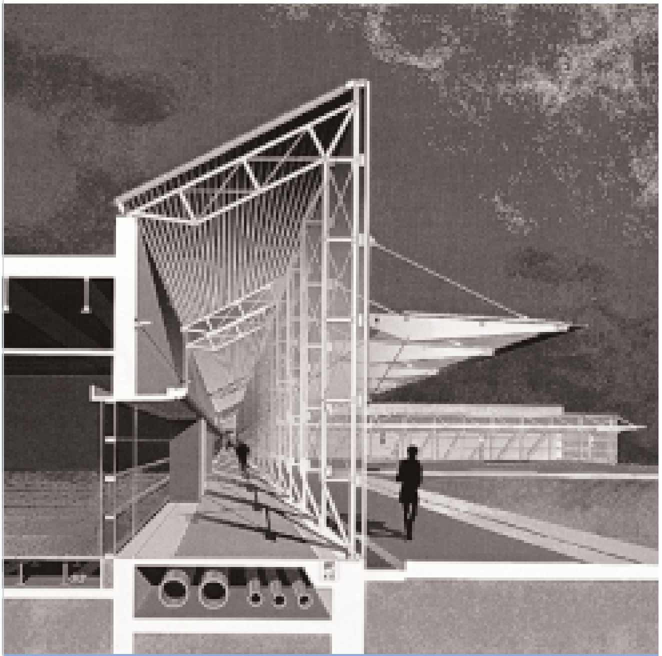
Mechanical equipment rooms must be designed in accordance with the requirements of *ASHRAE Standard 15: Safety Code for Mechanical Refrigeration*. Chiller leak detection and remote alarming shall be connected to the BAS.

Chillers. Chillers shall be specified in accordance with the latest Air-conditioning and Refrigeration Institute (ARI) ratings procedures and latest edition of the *ASHRAE Standard 90.1*. As a part of the life cycle cost analysis, the use of high-efficiency chillers with COP and IPLV ratings that exceed 6.4 (0.55 kW/ton) shall be analyzed. Likewise, the feasibility of gas-engine driven chillers, ice storage chillers, and absorption chillers shall be considered for demand shedding and thermal balancing of the total system.

BACnet or LONWORKS Microprocessor-based controls shall be used. Chiller staging controls shall be capable of DDC communication to the central building Energy Management System. The control panel shall have self-diagnostic capability, integral safety control and setpoint display, such as run time, operating parameters, electrical low voltage and loss of phase protection, current and demand limiting, and output/input-COP [input/output (kW/ton)] information.

When the peak cooling load is 1760 kW (500 tons) or more, a minimum of three chilled water machines shall be provided. The three units shall have a combined capacity of 120 percent of the total peak cooling load with load split percentages 40-40-40 or 50-50-20. If the peak cooling load is less than 1760 kW (500 tons), a minimum of two equally sized machines at 67 percent of the peak capacity (each) shall be provided. All units shall have adequate valving to provide isolation of the off-line unit without interruption of service. Cooling systems with a refrigeration capacity less than 176 kW (50 tons) shall use air-cooled chillers.

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



U.S. Census Bureau

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 chiller manufacturer's minimum.

Part load efficiency must be specified in accordance with ARI Standard 550/590.

The design of refrigeration machines must comply with Clean Air Act amendment Title VI: *Stratospheric Ozone Protection* and *Code of Federal Regulations* (CFR) *40*, Part 82: *Protection of Stratospheric Ozone.*

Chlorofluorocarbon (CFC) refrigerants are not permitted in new chillers. Commonly used refrigerants such as HCFC-22, HCFC-123, HFC-134a, and HFC-410a are acceptable. Except where justified based on life cycle cost, specifications shall not restrict the refrigerant type due to the anti-competitive nature of such restrictions on available chiller products.

Refrigeration machines 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 Clean Air Act, Title VI. Chillers must also be easily accessible for internal inspections and cleaning.

Thermal Storage Systems. Ice-on-coil systems shall be considered in locations where the life cycle cost analysis demonstrates economic justification. Thermal storage systems shall include prefabricated tanks with glycol coils and water inside the tank. The tank shall be insulated and its capacity and performance shall be guaranteed by the vendor. Self-contained, fabricated ice storage system shall have self-contained BACnet LONWORKS microprocessor controls for charging and discharging the ice storage system and capable of being connected to a central building automation system. Other types of ice storage systems are not permitted.

Condenser Water. All water-cooled condensers must be connected to a recirculating heat-rejecting loop. The heat rejection loop system shall be designed for a 5.5°C (10°F) temperature differential and a minimum of 3.9°C (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 down to 0.9 m (3 ft) below grade.

Cooling Towers. Multiple cell towers and isolated basins are required to facilitate operations, maintenance and redundancy. The number of cells shall match the number of chillers. Supply piping shall be connected to a manifold to allow for any combination of equipment use. Multiple towers shall have equalization piping between cell basins. 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 components. Variable speed pumps for multiple cooling towers shall not operate below 30 percent of rated capacity.

Induced draft cooling towers with multiple-speed or variable-speed condenser fan controls shall be provided. Induced draft 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.

The cooling tower's foundation, structural elements and connections shall be designed for a 45 m/s (100 mph) 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. 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 reroofing beneath the tower.

Special consideration shall be given to de-icing cooling tower fills if they are to operate in sub-freezing weather, such as chilled water systems designed 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 with waterside economizers and designed for year-round operation shall be equipped with basin heaters. Condenser water piping located above-grade and down to 3 feet below grade shall have heat tracing. Cooling towers shall be provided with BACnet or LONWORKS microprocessor controls, capable of connecting to central building automation systems.

See Chapter 7, *Fire Protection Engineering & Life Safety*, for fire protection provisions for cooling towers.

Chilled Water and Condenser Water Pumps. Pumps shall be of a centrifugal type and shall generally be selected to operate at 1750 RPM. Both partial load and full load must fall on the pump curve. The number of primary chilled water and condenser water pumps shall correspond to the number of chillers, and a stand-by pump shall be designed for each chilled water and condenser water circuit. Variable volume pumping systems shall be considered for all secondary piping systems with pump horsepower greater than 11.2 kW (15 hp). The specified pump motors shall not overload throughout the entire range of the pump curve.

Each boiler cooling tower and chiller group pumps shall be arranged with piping, valves, and controls to allow each chiller-tower group to operate independently of the other chiller and cooling tower groups.

Freeze Protection. Propylene glycol manufactured specifically for HVAC Systems is used for freeze protection, primarily in low temperature chilled water systems (less than 4.4°C) (less than 40°F). The concentration of antifreeze shall be kept to a practical minimum because of its adverse effect on heat exchange efficiency and pump life. The water make-up line for glycol systems shall be provided with an in-line water meter to monitor and maintain the proper percentage of glycol in the system. All coils exposed to outdoor airflow (at some time) shall be provided with freeze protection thermostats and control cycles. Provisions shall be made for drain down, storage and re-injection of the glycol into the system.

Waterside Economizer Cycle. In certain climate conditions cooling towers are capable of producing condenser water cold enough to cool the chilled water system without chiller operation. This option shall be considered in life cycle cost analysis of water cooled chillers. Waterside economizer cycles are particularly cost effective in the low humidity climates of the western United States. Waterside economizer systems shall be used only in areas where the outdoor air temperature shall be below 4.4°C (40°F) wet bulb. Waterside economizers shall utilize a plate heat exchanger piped in parallel arrangement with its respective chiller.

5.12 Pumping and Piping Systems

All HVAC piping systems shall be designed and sized in accordance with *ASHRAE Fundamentals Handbook* and the *ASHRAE HVAC Systems and Equipment Handbook*. Materials acceptable for piping systems are black steel and copper. No PVC or other types of plastic pipe are permitted.

The hot water and chilled water systems shall utilize a two-pipe main distribution system arranged in a reverse return configuration. Loop piping for terminal or branch circuits shall be equipped with automatic flow control valves. Each terminal unit or coil shall be provided with isolation valves on both the supply and return, and a flow-indicating balance valve on the return line. Isolation valves shall be provided on all major pipe branches, such as at each floor level, building wing or mechanical room.

Hydronic, Closed Loop Systems. Pumps used in closed loop hydronic piping shall be designed to operate to the left of the peak efficiency point on their curves (higher head, less flow), to compensate for variances in pressure drop between calculated and actual values without causing pump overloading. Pumps with steep curves shall not be used, as they tend to limit system flow rates. Flow may be varied by variable speed pumps or staged multiple pumps. Pumps shall operate at no less than 75% efficiency on their performance curve.

Variable Primary Pumping. In this application, the primary circuit serves source equipment (chiller or boiler) and the load. The primary loop and pumps are dedicated and sized to serve the flow and temperature differential requirements of the primary source equipment and the load. Variable primary systems are only recommended for smaller buildings [circulation of less than 63.1 L/s (1,000 gpm)].

In variable primary applications, many conventional chillers and boilers may experience flow-related heat exchange problems when a minimum flow is not maintained. For this reason, all variable primary applications must follow manufacturers' recommended practices to prevent equipment damage or failure.

Primary/Secondary Pumping. In this application, primary and secondary circuits are separate, with neither having an effect on the pumping head of the other. The primary circuit serves source equipment (chiller or boiler), while the secondary circuit serves the load. The primary loop and pumps are dedicated and sized to serve the flow and temperature differential requirements of the primary source equipment. This permits the secondary pump and loop to be sized and controlled to provide the design flow rate and temperature differential required to satisfy the heating or cooling loads. Primary/secondary systems are recommended for larger buildings [circulation of more than 63.1 L/s (1,000 gpm)] and campus facilities.

Air Control. Pressurized diaphragm expansion tanks shall be used in appropriately sized manufactured products. Air separators and vents must be provided on hot water systems to remove accumulated air within the system. Automatic bleed valves shall only be used in accessible spaces in mechanical rooms where they can be observed by maintenance personnel and must be piped directly to open drains. Manual bleed valves shall be used at terminal units and other less accessible high points in the system. Air vents shall be provided at all localized high points of the piping systems and at each heating coil. Likewise, system drains shall be provided at all localized low points of the heating system and at each heating coil.

Cathodic Protection. The need for corrosion protection for underground metallic piping must be evaluated by a soils resistivity test. Cathodic protection or another means of preventing pipe corrosion must be provided if required by the Geotechnical Report.

Dielectric Unions. Dielectric unions must be provided when connecting dissimilar materials in piping systems.

Piping Material. Table 5-5 cites which commercial standard shall be used for piping material.

Isolation of Piping at Equipment. Isolation valves, shutoff valves, by-pass circuits, flanges and unions shall be provided for piping at equipment to facilitate equipment repair and replacement. Equipment requiring isolation includes boilers, chillers, pumps, coils, terminal units and heat exchangers. Valves shall also be provided for zones off vertical risers.

Flexible Pipe Connectors. Flexible pipe connectors shall be fabricated from annular close pitched corrugated and braided stainless steel. All pumps, chillers, and cooling towers shall have flexible connectors.

Piping System and Equipment Identification. All pipes, valves and equipment in mechanical rooms, shafts, ceilings and other spaces accessible to maintenance personnel must be identified with color-coded bands and permanent tags indicating the system type and direction of flow for piping systems or type and number for equipment, per *ASHRAE Handbook*. The identification system shall also tag all valves and other operable fittings. Gas piping and sprinkler lines must be identified as prescribed by NFPA.

Table 5-5
Commercial Standards for Piping Material

Standard Piping Material	Use	Comments
ASTM Schedule 40	Chilled water up to 300 mm (12 in) dia., Condenser water up to 300 mm (12 in) dia.	1035 kPa (150 psi) fittings. Standard weight pipe over 300 mm (12-in) diameter.
	Hot water up to 100 mm (4 in) dia.	Test to 2100 kPa (300 psig)
	Natural gas, fuel oil	Weld and test to 2100 kPa (300 psig)
	Steam (100 kPa (15 psig) to 1035 kPa (150 psi))	
ASTM Schedule 30	Chilled water over 300 mm (12 in) dia Condenser water over 300 mm (12 in) dia.	1035 kPa (150 psi) fittings. Standard weight pipe over 300 mm (12-in) diameter
ASTM Schedule 80	Steam condensate	
Copper Tubing	Chilled water up to 102 mm (4 in) dia, Condenser water up to 102 mm (4 in) dia.	Builder's option. Use type K below ground and type L above.
	Domestic water	Lead-free solder connections.
	Refrigeration	Type ACR.
	Cast Iron Sanitary, waste and vent	
	Storm	

5.13 Thermal Insulation

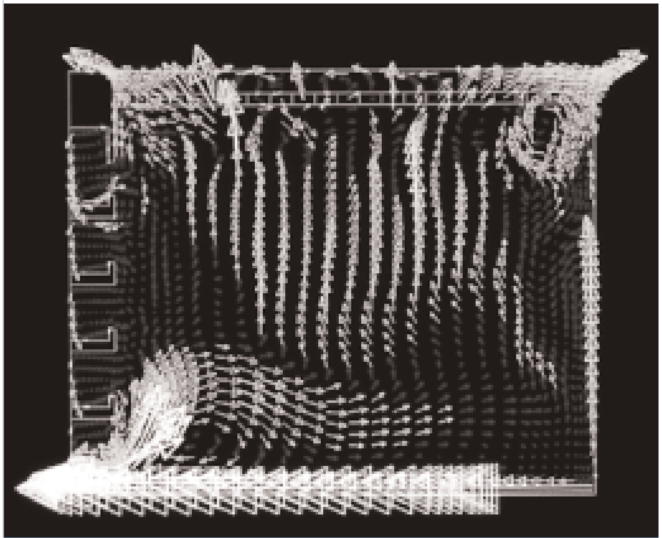
General

All insulation materials shall comply with the fire and smoke hazard ratings (25 for flame spread; 50 for smoke developed) as indicated by ASTM-E84, NFPA 255 and UL 723. Accessories such as adhesives, mastics, cements and tapes shall have the same or better fire and smoke hazard ratings.

Insulation shall be provided in accordance with *ASHRAE Standard 90.1*. Insulation that is subject to damage or reduction in thermal resistivity if wetted shall be enclosed with a vapor seal (such as a vapor barrier jacket).

Duct Insulation. All exposed ductwork shall have sealed canvas jacketing. All concealed ductwork shall have foil face jacketing.

The insulation shall comply with fire and smoke hazard ratings indicated by ASTM-E84, NFPA 255 and UL 723.



Air Flow Diagram, Atrium, Phoenix Courthouse

Accessories such as adhesives, mastics, cements, tapes, etc. shall have the same or better component ratings. All supply air ducts must be insulated, in accordance with *ASHRAE Standard 90.1*. Supply air duct insulation shall have a vapor barrier jacket. The insulation shall cover the duct system with a continuous, unbroken vapor seal.

Return air and exhaust air distribution systems shall be insulated in accordance with *ASHRAE Standard 90.1*. The insulation of return air and exhaust air distribution systems needs to be evaluated for each project and for each system to guard against condensation formation and heat gain/loss on a recirculating or heat recovery system. Generally, return air and exhaust air distribution systems do not require insulation if located in a ceiling plenum or mechanical room used as a return air plenum. All equipment, heat exchangers, converters and pumps shall be insulated as per *ASHRAE Standard 90.1*.

Piping Insulation. All insulation material shall comply with the fire and smoke hazard ratings indicated by ASTM-E84, NFPA 255 and UL 723. Accessories such as adhesives, mastics, cements, tapes, etc. shall have the same or better component ratings. All piping systems must be insulated in accordance with *ASHRAE Standard 90.1*. Piping systems conveying fluids having design temperatures less than 18.3°C (65°F) or greater than 40.6°C (105°F) shall be insulated. All piping systems with surface temperatures below the average dew point temperature of the indoor ambient air and where condensate drip will cause damage or create a hazard shall be insulated with a vapor barrier to prevent condensation formation regardless as to whether piping is concealed or exposed. Chilled water piping systems shall be insulated with nonpermeable insulation (of perm rating 0.00) such as cellular glass. All exposed and concealed piping shall have PVC jacketing.

Equipment Insulation. All insulation material shall comply with the fire and smoke hazard ratings indicated by ASTM-E84, NFPA 255 and UL 723. Accessories such as adhesives, mastics, cements, tapes, etc. shall have the same or better component ratings. All equipment including air-handling units, chilled and hot water pumps, and heat exchangers must be insulated in accordance with *ASHRAE Standard 90.1*. All pumps shall have jacketing.

Thermal Pipe Insulation for Plumbing Systems

All sanitary sewer vents terminating through the roof shall be insulated for a minimum of 1.83 meters (6 feet) below the roof line to prevent condensation from forming and include a vapor barrier jacket on this insulation. All Insulation materials and accessories shall comply with the fire and smoke hazard ratings indicated by ASTM-84, NFPA 255 and UL 723.

Domestic water piping shall be insulated in accordance with *ASHRAE Standard 90.1*. All piping exposed in plenums or above ceiling shall be insulated to prevent condensation. All insulation materials and accessories shall comply with the fire and smoke hazard ratings indicated by ASTM-E84, NFPA 255 and UL 723.

5.14 Vibration Isolation, Acoustical Isolation, and Seismic Design for Mechanical Systems

Noise and Vibration Isolation. Refer to and incorporate the basic design techniques as described in Chapter 3 *Acoustics, Design Criteria for Building Spaces* and *ASHRAE Applications Handbook, Sound and Vibration Control*. Isolate all moving equipment in the building.

Mechanical Room Isolation. Floating isolation floors shall be considered for major mechanical rooms located in penthouses or at intermediate levels in mid-rise and high-rise construction.

Mechanical Shafts and Chases. Mechanical shafts and chases shall be continuous and closed at the top and bottom. Any piping and ductwork shall be isolated as it enters the shaft to prevent propagation of vibration to the building structure. All openings for ducts and piping must be sealed. Shafts dedicated to gas piping must be ventilated.

Isolators. Isolators shall be specified by type and by deflection, not by isolation efficiency. See *ASHRAE Guide for Selection of Vibration Isolators* and *ASHRAE Application Handbook* for types and minimum deflections. Specifications shall be worded so that isolation performance becomes the responsibility of the equipment supplier.

Concrete Inertia Bases. Inertia bases shall be provided for reciprocating and centrifugal chillers, air compressors, all pumps, axial fans above 300 RPM, and centrifugal fans above 37.3 kW (50 hp).

Ductwork. Reduce fan-generated noise immediately outside of any mechanical room wall by acoustically coating or wrapping the duct. The ductwork design shall appropriately consider and address airborne equipment noise, equipment vibration, ductborne fan noise, duct breakout noise, airflow generated noise and ductborne crosstalk noise. All ductwork connections to equipment having motors or rotating components shall be made with 6-inch length of flexible connecters. All ductwork within the mechanical room or serving courtrooms shall be supported with isolation hangers.

Piping Hangers and Isolation. Isolation hangers shall be used for all piping in mechanical rooms and adjacent spaces, up to a 15.2 m (50 ft) distance from vibrating equipment. The pipe hangers closest to the equipment shall have the same deflection characteristics as the equipment isolators. Other hangers shall be spring hangers with 19 mm (0.75 in) deflection. Positioning hangers shall be specified for all piping 203 mm (8 in) and larger throughout the building. Spring and rubber isolators are recommended for piping 51 mm (2 in) and larger hung below noise sensitive spaces.

Floor supports for piping may be designed with spring mounts or rubber pad mounts. For pipes subject to large amounts of thermal movement, plates of Teflon or graphite shall be installed above the isolator to permit horizontal sliding.

Anchors and guides for vertical pipe risers usually must be attached rigidly to the structure to control pipe movement. Flexible pipe connectors shall be designed into the piping before it reaches the riser.

Provisions for Piping in Earthquake Zones. In regions of moderate and high seismicity, sleeves for pipes shall be at least 25 mm (1 inch) larger than the pipe, to allow for movement. Flexible couplings shall be provided at the bottom of pipe risers. Spreaders shall be used to separate adjacent pipes, unless the distance is large enough to prevent contact in an earthquake. See Chapter 4: *Structural Engineering, SMACNA Seismic Restraint Manual and ASHRAE Application Handbook* for more detailed information.

Piping Supports. Provide channel supports for multiple pipes and heavy duty steel trapezes to support multiple pipes. Hanger and support schedule shall have manufacturer's number, type and location. Comply with MSS SP69 for pipe hanger selections. Spring hangers and supports shall be provided in all the mechanical rooms.

Noise Control in Duct Systems. System sound levels at maximum flow must be carefully evaluated to ensure acoustic levels required in Chapter 3. Duct noise control shall be achieved by controlling air velocity, by the use of sound attenuators, by the use of double wall ductwork with insulation in-between (only on courtroom return air transfer grilles) and by not oversizing terminal units. Duct liners are not permitted as a means of sound attenuation. Terminal units shall be selected so that design air volume is approximately three-quarters of the terminal box's maximum capacity. Volume dampers in terminal units shall be located at least 1.8 m (6 ft) from the closest diffuser and the use of grille mounted balance dampers shall be restricted except for those applications with accessibility problems.

Noise Transmission Attenuation (Courthouses). Attenuate noise transmission to and from courtrooms, judges' chambers, jury rooms, prisoner consulting rooms and from prisoner detention areas.

5.15 Meters, Gauges, and Flow Measuring Devices

Thermometers and Gauges. Each piece of mechanical equipment shall be provided with the instrumentation or test ports to verify critical parameters, such as capacity, pressures, temperatures, and flow rates. Following are the general instrumentation requirements:

- 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. To avoid pressure gauge tolerance errors, a single pressure gauge may be installed, valved to sense both supply and return conditions. For coils with less than 0.63 L/s (10 gpm) 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 air-handling unit 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 air-handling units and to measure building pressure relative to the outdoors. A temperature gauge is required at the outdoor air intake to each air-handling unit.

Flow Measuring Devices. Airflow measuring grids are required for all central air-handling units. Measuring grids shall be provided at the supply air duct, return air duct, and the outdoor air duct. Airflow measuring grids must be sized to give accurate readings at minimum flow. It may be necessary to reduce the duct size at the station to permit accurate measurement.

Water flow or energy measuring devices are required for each chilled water refrigeration machine, hot water boiler, pump, and connections to district energy plants. Individual water flow or energy measuring devices shall be provided for chilled water lines serving computer rooms and chilled water and hot water lines to outleased spaces. Flow measuring devices shall be capable of communicating with the central BAS. Water flow and air flow measuring devices shall confirm to *ASHRAE Standard 90.1* requirements.

Testing Stations. Permanent or temporary testing stations shall be provided for start up and testing of building systems. Connections shall be designed so temporary testing equipment can be installed and removed without shutting down the system.

College Park, Maryland chilled water supply and return

5.16 Building Automation Systems (BAS)

The BAS shall be Direct Digital Control (DDC) for providing lower operating costs and ease of operation. The BAS shall adjust building systems to optimize their performance and the performance with other systems in order to minimize overall power and fuel consumption of the facility.

BAS shall utilize 'open' communication protocols, such as BACnet or LONWORKS, to minimize the costs of providing integration and to 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 central strategies. A/E to specify and include functional design manual, hardware manual, software manual, operation manual, and maintenance manual. BAS shall have energy management and monitoring software.

In retrofits with an existing old-proprietary system in place, it is recommended that life cycle cost analysis determine between the complete replacement of the existing system or integrating the existing system with customized gateways. In the long term, with hardware and software costs falling as capabilities increase, energy savings are producing the paybacks required to justify the complete control retrofit.

The system shall consist of series of direct digital controllers interconnected by a local area network. BAS system shall be accessible through a web browser. System shall have a graphical user interface and must offer trending, scheduling, downloading memory to field devices, real-time "live" graphic programs, parameter changes of properties, setpoint adjustments, alarm/event information, confirmation of operators, and execution of global commands.

BAS is required for large facilities, both new facilities and major modernizations, [above 9,290 gross m^2 (100,000 gross sq. ft)]. Smaller projects shall be evaluated to determine the need for a BAS. The size of the building, number of pieces of equipment, expected energy savings and availability of trained staff shall all be considered.

Level of Integration

When planning BAS systems with a high level of integration, the necessary training will be required for the operating staff.

Lighting systems shall not be controlled by a BAS. These systems shall have independent control panels and networks. The BAS system shall monitor the status of the lighting systems only.

Fire alarm systems, security systems and elevator systems shall not be controlled by a BAS. These systems shall have independent control panels and networks. The BAS system shall monitor the status of these systems only, in order to prompt emergency operating modes of HVAC and lighting systems. See Chapter 7: *Fire Protection & Life Safety, Electrical Requirements, Fire Alarm Systems*, and Chapter 8: *Security Design*.

Automatic Temperature and Humidity Controls

A direct digital control (DDC) system with host computer monitoring and control shall be provided.

Temperature Controls. Pre-programmed stand-alone single or multiple loop microprocessor PID controllers shall be used to control all HVAC and plumbing subsystems. PID loops shall be utilized. All chillers, boilers, terminal units and air-handling units shall have self-contained BACnet or LONWORKS controllers, capable of communicating with the Building Automation System.

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.

A 2.8°C (5°F) dead band shall be used between independent heating and cooling operations within the same zone.

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 must be part of the control system. Controls for the various operating conditions must include maintaining pressurization requirements.

Humidity Controls. 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 provide more stable humidity levels. However, RH sensors are acceptable, provided they have been calibrated in-place, and provided that they have co-located with dry bulb sensors so that the BAS can convert these two signals to a dew point value for control purposes.

Setpoint Reset Controls

Air Systems. Systems supplying heated or cooled air to multiple zones must include controls that automatically reset supply air temperature required by building loads or by outdoor air temperature.

Hydronic Systems. Systems supplying heated and/or chilled water to comfort conditioning systems must also include controls that automatically reset supply water temperatures required by temperature changes responding to changes in building loads (including return water temperature) or by outdoor air temperature.

Energy Management and Conservation

HVAC control algorithms shall include optimized start/stop for chillers, boilers, air-handling units and all associated equipment and feed forward controls based on predicted weather patterns. Lighting control shall be accomplished by use of separate control equipment, which allows BAS monitoring and reporting and control settings. Optimal start/stop calculates the earliest time systems can be shut down prior to the end of occupancy hours and the latest time systems can start up in the morning with the aim of minimizing equipment run time without letting space conditions drift outside of the comfort setpoints. Weather prediction programs store historic weather data in the processor memory and use this information to anticipate peaks or part load conditions. Programs also run economizer cycles and heat recovery equipment.

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. Electrical values, such as V, A, kW, KVAR, KVA, PF, kWh, KVARH, Frequency and Percent THD, shall be measured. See also Chapter 6: *Electrical Engineering*, for separate metering of power consumption.

Energy management measurements shall be totalized and trended in both instantaneous and time-based numbers for chillers, boilers, air-handling units and pumps. Energy monitoring data shall be automatically converted to standard database and spreadsheet format and transmitted to a designated workstation. Energy points are those points that are monitored to ensure compliance with *ASHRAE Standard 90.1*.

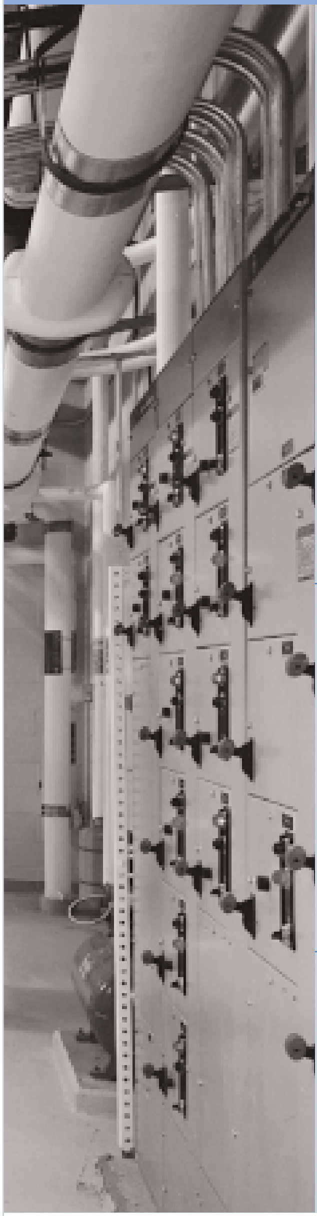
Maintenance Scheduling

The BAS shall include programs for control that switch pumps and compressors from operating equipment to stand-by on a scheduled basis. Also, programs that provide maintenance schedules for equipment in every building system shall be included, complete with information on what parts and tools are needed to perform each task.

System Design Considerations

BAS's require measurements at key points in the building system to monitor part-load operation and adjust system setpoints to match system capacity to load demands. Table 5-6 of the previous section outlines the minimum control and monitor points for typical HVAC equipment. Controls cannot correct inadequate source equipment, poorly selected components, or mismatched systems. Energy efficiency requires a design that is optimized by realistic prediction of loads, careful system selection, and full control provisions. System ability must include logs of data created by user selectable features. In new buildings and major renovations, the BAS shall have approximately 20 percent spare capacity for future expansion. The system must provide for stand-alone operation of subordinate components. The primary operator workstation shall have a graphical user interface. Standalone control panels and terminal unit controllers can have text-based user interface panels which are hand-held or fixed.

Table 5-6
Minimum Control and Monitoring Points for Typical HVAC Equipment



Central Air Handling Units
Start/Stop
Heating Control
Cooling Control
Humidification Control
Supply Air Reset
Static Pressure Reset
Building and Zone
Pressurization Control
Damper Position (economizer)
Supply Air Discharge Temp
Return Air Temp
Mixed Air Temp
Supply Air Flow Rate
Filter Differential Pressure
Air Flow Measuring Station

Refrigeration Equipment
Start/Stop
Leave Water Temp Reset
Demand Limiting
Isolation Valve Position
Leaving Water Temp
Entering Water Temp
kW Draw
Flow
Return Air Flow Rate

Hot Water Boilers
Start/Stop
Leaving Water Temp Reset
Reset
Isolation Valve Position
Leaving Water Temp
Entering Water Temp
Flow
BTU Draw

Cooling Towers
Start/Stop
Leaving Water Temp Reset
Flow
Isolation Valve Position
Entering Water Temp
Leaving Water Temp

Terminal Boxes
Start/Stop
Discharge Temp Reset
Supply Volume Reset
Heating Control
Zone Temp Reset
Minimum Volume Reset
Zone Temp
Supply Air Reset
Zone Pressurization Control

Pumps
Start/Stop
Discharge Pressure Reset
Differential Pressure
Flow

Utilities
Natural Gas Consumption
Electricity Consumption & Demand
Water Consumption
Fuel Oil Quantity

5.17 Testing and Balancing

Startup. The A/E shall specify that factory representatives be present for startup of all major equipment, such as boilers, chillers, air-handling units, packaged pump systems, and automatic control systems.

Testing and Balancing. It shall be the responsibility of the A/E to adequately specify testing, adjusting and balancing resulting in not only proper operation of individual pieces of equipment, but also the proper operation of the overall HVAC and Plumbing systems, in accordance with the design intent. The Testing and Balancing contractor shall have up to date certification by Associated Air Balance Council (AABC), the National Environmental Balance Bureau (NEBB), or the Testing, Adjusting, and Balancing Bureau (TABB).

Performance Testing. A/E to specify performance testing of all systems and equipment including chillers, boilers, air-handling units, exhaust fans, water heaters, and other systems for part load and full load during summer, winter, spring and fall season as per the schedules specified by the designer. The A/E shall specify the services of an organization certified by NEBB or AABC. Performance testing of domestic water heating systems shall include heater and remote outlet temperature maintenance, system and circuit pressure equalization (without over pressurization, excess pressure loss, or return pump dead-head), and control of water hammer at peak draw. Test for compliance with specifications and design intent for operation of water heater(s), mixing valve(s), circuit setters/balancing valves, return pump(s), and pressure reducing/regulating valves.

Ductwork Pressure and Leak Testing. Tests shall be conducted at static pressures equal to maximum design pressure of system and maximum leakage allowable shall not exceed 50 percent of that allowed in *SMACNA's HVAC Air Duct Leakage Manual*.

Piping and Equipment Pressure and Leak Testing. Leak testing shall be conducted at static pressures as required by code (or as 120 percent of maximum design working pressure of system where no code requirement exists), with maximum permissible leakage.

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5.18 Plumbing Systems

Water conservation shall be a requirement of all plumbing systems. Use water-saving plumbing fixtures.

Domestic Water Supply Systems

Domestic Cold Water Service. Domestic potable cold water service shall consist of a pressurized piping distribution system incorporating an independent (separate) service pipe from the tap at the exterior utility service water main to the water meter and backflow preventer equipment inside the building.

Water service meters shall be located inside the building, utilizing meters (generally) furnished by the water utility purveyor, to maintain security and supervision within the security perimeter. Exterior water meter crocks or vaults shall not be permitted. Water meters shall be remote reading type with transponder signal transmitted by telephone line. Irrigation systems, and similar water supply/make-up systems that do not discharge to the sanitary sewer, shall be sub-metered (remote read) for utility billing rate deduction of sanitary service not utilized. The water service shall have a code and water purveyor compliant reduced pressure zone backflow prevention device immediately downstream of the service water meter(s) prior to all other connections and branches. Maintain manufacturer and water purveyor required access and service clearances for meters and backflow preventers.

Internal distribution shall consist of a piping system that supplies domestic potable cold water to all plumbing fixtures, plumbing equipment, water heaters, mechanical make-up, and cold water equipment/system demands.

Domestic Water Service Pressure Maintenance. Distribution water pressure shall provide fixture, equipment, and outlet required pressures at the hydraulically most demanding (generally the topmost/highest and most remote) outlet. Required outlet pressure shall be minimum requirements of code, or higher requirements of the fixture, equipment, or outlet demand as identified by the manufacturer or warrantee.

Distribution water pressures shall not exceed system material, piping, and device rated maximum working pressures, or maximum pressures at the fixture, equipment, or outlet as required by code. The A/E shall schedule and specify pressure regulating valves or valve stations where pressures at maximum working pressure (High HGL, plus booster pump shut-off pressure for boosted systems) may exceed code maximum, or manufacturer/warranty maximum operating pressures (generally lower than code maximums. Pilot operated pressure reducing valves (or valve stations) with expansion by-pass (for domestic hot water) shall be utilized to regulate supply water pressures within distribution zones. Individual outlets may utilize pressure reducing valves compliant with code requirements and as recommended by the outlet use manufacturer. Pressure reducing valves shall be specified to operate at peak flow within the entire range of Low HGL and maximum working pressure of the system (High HGL, plus pump shut-off head for pressure boosted systems).

A packaged and third party tested triplex (three pump) booster pumping system or duplex (two pump) with 120-170 gallon hydropneumatic storage pressure tank, shall be utilized where water flow test and water purveyor low hydraulic grade line (Low HGL) water pressures do not provide required pressure demands at peak draw. Water pressure boosting shall generally be provided only to those areas, or floor elevations where insufficient water pressures may be experienced/expected utilizing the Low HGL. Outlets on floor elevations or areas that can be served with the required pressures provided at Low HGL shall not be pumped. The entire water service shall not be pressure boosted if only portions of the building systems require pressure maintenance boosting.

The water service supply source (utility) low hydraulic grade line (Low HGL), low head elevation of water source tank or pump, adjusted for friction and head losses/gains, shall be utilized for determining available water source pressure, pump suction calculations and selection. The water service supply source (utility) high hydraulic grade line (High HGL), high head elevation of utility service water supply source tank or pump, plus booster pump shut-off head for boosted systems (system maximum working pressure), adjusted for static pressure head losses/gains, shall be utilized for determining maximum system working pressures.

Domestic Hot Water Service. 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 in conjunction with the HVAC energy provisions.

Cold (or preheated) water supply to water heaters shall include service valve, check valve, expansion tank (sized for expansion of storage capacity only), 27'' heat trap, mixing valve by-pass primer, and hot water return connection as a minimum. 27'' 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 A/E shall obtain, from the water utility purveyor, seasonal cold water service temperatures supplied by the water utility purveyor (past three year minimum preferred). Low temperature (lowest of past three years) seasonal cold water service temperatures shall be utilized in calculation and application of water heating, water heating energy source (steam, heating hot water, gas), and for make-up to the water heating energy source. Preheating of domestic cold water supply to the domestic water heater and cold water make-up to water heating energy source shall be considered utilizing steam condensate or heating hot water return.

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.

Domestic hot water supply temperatures shall be generated and stored at a minimum of 60.0°C (140°F), and tempered to deliver 51°C (124°F) to outlets, where permitted by state code. Hand washing, lavatory, sink and similar fixtures accessible to the disabled, elderly, or children shall be tempered to deliver 29°C (85°F) - 63°C (109°F) water temperatures at the fixture or group of battery fixtures. Bathing and showering fixtures (except emergency showering) shall be tempered to deliver “tempered water” 29°C (85°F) - 49°C (120°F) water temperatures at the fixture or group of battery fixtures. Individual fixture or battery thermostatic mixing valves shall be provided where distributed, or zone, outlet temperatures may exceed 51°C (124°F). Hot water supply to dishwashers shall be at 60°C (140°F), and the temperature shall be boosted from 60°C (140°F) to 82°C (180°F) for final sanitizing rinse. Heat pump hot water heaters shall be used where possible to save energy.

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" 29°C (85°F) - <37.8°C (100°F), at 0.207 megapascal (30 psi), within 10 seconds, for a minimum period of 15 minutes, and shall account for temperature drop across the valve (generally 7°C or 20°F) at flow.

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 Center for Disease Control (CDC) "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 (1999) "Emergency Eyewash and Shower Equipment." 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 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 result of pressure zoning or static head cannot successfully be joined to a single pressure zone water heater. Locate individual pressure zone water heater(s) 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.

Domestic Water Supply Equipment. Domestic water supply equipment and components shall include, but not be limited to, the following equipment: water meters, water heaters, water filtration, water softening, pressure booster systems, pressure regulating valves, circulating pumps, backflow preventers, circuit setters/balancing valves, thermostatic mixing valves, expansion tanks, isolation valves, hangers and supports, and thermal insulation.

Water heaters and expansion tanks shall be compliant with ASME, stamped and rated.

Water hammer arrestors shall be provided at each elevation change of every horizontal branch to fixture batteries, at all quick-closing automatic valves (mechanical make-up, drinking fountains, flush valves, single lever control faucets, temperature regulating valves, dishwashers, return pumps, and similar), and at each floor on each horizontal main for branches with/without individual fixture or battery water hammer arrestors, for both hot and cold water. Water hammer arrestors shall be compliant with the Plumbing and Drainage Institute (PDI) Standard PDI-WH201, ANSI/ASME A112.26.1M, or as required by code, and as recommended/required by fixture and equipment manufacturer, or warranty.

Domestic cold and hot water distribution systems shall be insulated per *ASHRAE Standard 90.1* with vapor barrier for concealed and above ceiling piping, canvas jacketing and vapor barrier where exposed in mechanical areas, and vapor barrier with PVC jacketing where exposed in other than mechanical areas.

Sanitary (Soil and Waste), and Vent System

Sanitary Pipe and Fittings. A complete sanitary building drainage system shall be provided for all plumbing fixtures, sanitary floor drains, kitchen equipment, and 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). Above ground piping shall have hubless (no-hub) fittings and joints (by pipe manufacturer) with pipe support compliant with hubless (no-hub) pipe standard compliant with code (generally within 12 inches of each side of each joint).

Vent Piping and Fittings. Piping shall be service weight cast iron soil pipe with hub and spigot fittings and joints with elastomeric gasket (by pipe manufacturer). Above ground piping shall have hubless (no-hub) fittings and joints (by pipe manufacturer), or Type-K DWV copper with 95-5 tin antimony solder joints.

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 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. Receptors, open-site drains, hub drains, trench drains, and similar drains shall have dome bottom strainer (in addition to pedestrian/vehicle grate strainers where required) to reduce splashing, increase free area, and prevent debris blockage. Drain body, frame and grate strainers shall be rated for expected wheel loading, and shall include drain adapters, extensions, receivers, deck clamps, and similar as required by building construction. Drain strainer free area shall be equal to or greater than the free area of the calculated outlet pipe size area. Drain strainers in pedestrian areas shall be heel-proof type. Every drain and system opening shall have ¼" maximum strainer openings for rodent-proofing. Discharges shall be elastomeric pinch valves or similar for rodent-proofing. Receptor drains outlets shall be two-times the area of combined inlet pipe areas. Equipment room areas shall require large diameter cast iron strainers, and parking garages shall require large diameter tractor grates rated for expected wheel loading. Drainage for ramps shall require either trench drains or roadway inlets when exposed to rainfall. 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.

Sanitary Waste Equipment

Grease Interceptors. Drains and fixtures discharging fat, oil, or grease laden waste; within 10 feet of the cooking battery, mop and service sinks in kitchen areas; and as required by the state health department and local authorities, shall discharge to a grease interceptor prior to connecting into the sanitary sewer. Grease interceptors shall be sized compliant with requirements of the local authority. Where permitted by the local authority, grease interceptors shall be compliant with the Plumbing and Drainage Institute (PDI) PDI-G101. Drains, fixtures, and equipment required to discharge to the grease interceptor shall be as required by the state health department and local authorities. Generally food grinders, vegetable sinks, fish scaling sinks (provide separator), meat cutting sinks, and clear water wastes are prohibited by the local authority from extending to the grease interceptor, and shall not be employed except where otherwise required by the local authority.

Sand/Oil Separator. Floor drains and/or trench drains in vehicle repair garages shall discharge to a sand/oil separator prior to discharge to the sanitary sewer.

Automatic Sewage Ejectors. 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 102 mm (4 in) in diameter. They shall be connected to the emergency power system.

Sanitary Drainage. Clearwater drainage: storm rain water, cooling coil condensate drainage, and similar clearwater 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 drainage system for treatment and protection of the environment and waterways. Purified steam (i.e. humidification) shall not discharge to the sanitary drainage system

Rainwater Drainage System

Rainwater Drainage (Storm) Pipe and Fittings. A complete rainwater (storm) building drainage system shall be provided for all rainwater (storm) drainage for roofs, plazas, balconies, decks, area wells, parking structures, parking garages, and similar. Clearwater drainage (cooling coil condensate drainage, evaporation pan drainage, ice makers) and similar clear, non-chemically treated drainage shall discharge to the rainwater (storm) drainage system, and not the sanitary drainage system. Clearwater drainage without chemical, vegetable, human, animal, protein, fecal, oil, grease or similar pollutants may be discharge to the rainwater (storm) drainage system where approved by code, state, local authority, and Environmental Protection Agency.

The rainwater (storm) and vent system shall be designed in compliance with applicable codes and standards. P-traps and house-traps shall only be provided on storm systems where required by code, state, or local authority.

Piping shall be service weight cast iron soil pipe with hub and spigot fittings and joints with elastomeric gasket (by pipe manufacturer). Above ground piping shall |have hubless (no-hub) fittings and joints (by pipe manufacturer) with pipe support compliant with hubless (no-hub) pipe standard compliant with code (generally within 12 inches of each side of each joint).

Rainwater (Storm) 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 gasket (by pipe manufacturer). Above ground piping shall have hubless (no-hub) fittings and joints (by pipe manufacturer), or Type-K DWV copper with 95-5 tin antimony solder joints.

Storm Drains. Rainwater (storm) drains include domed roof drains, secondary roof drains, hub and receptor drains (that do not receive floor drainage), deck drains, parking garage drains, trench drains, area well drains, and similar. 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 strainer (in addition to pedestrian/vehicle grate strainers where required) to reduce splashing, increase free area, and prevent debris blockage. Drain body, frame and grate strainers shall be rated for expected wheel loading, and shall include drain adapters, extensions, receivers, deck clamps, gravel stops and similar as required by building construction. Drain strainer free area shall be equal to or greater than the free area of the calculated outlet pipe size area. Drain strainers in pedestrian areas shall be heel-proof type. Every drain and system opening shall have ¼" maximum strainer openings for rodent-proofing. Discharges shall be elastomeric pinch valves or similar for rodent-proofing. In general, drains shall be cast iron body type with nickel-bronze strainers for finished pedestrian areas, aluminum domes for roof drains, ductile iron or bronze finish for unfinished pedestrian areas. Rainwater drains and equipment room areas shall require large diameter strainers. Drainage for ramps shall require either trench drains or roadway inlets when exposed to rainfall. Trap primers shall be provided for P-traps (where P-traps are required by code, state, or local authority).

Rainwater (Storm) Equipment

Sand/Oil Separator. Drains in parking structures and garage shall discharge to a sand/oil separator prior to discharge to the storm sewer when required by code, state, or local authority.

Automatic Sump Pumps. Sump pumps shall only be used where gravity drainage is not possible. Only rainwater, 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. Sump pumps shall be connected to the emergency power system.

Foundation and sub-soil drainage system shall be provided with emergency power source, backwater prevention, perforated drain tile piping in washed gravel bed with filter fabric shall extend to duplex sump pumping system as required by the applicable codes.

The requirements of the foundation and sub-soil drainage system shall be identified, capacity calculated, and materials identified by the Geotechnical soils engineer and identified in the geotechnical report. The layout and installation details and materials (identified by the geotechnical report) shall be specified and identified in the structural foundation drawings, and indicated on the architectural drawing sections and details. The extension from the system end to the sump pump or daylight termination shall be identified on the plumbing drawings.

Sanitary Drainage. Clearwater drainage: storm rain water, cooling coil condensate drainage, foundation, sub-soil, groundwater, and similar clear water drainage shall not discharge to the sanitary drainage system.

Chemically treated mechanical discharge from cooling towers, boilers, chillers, and blow down shall discharge to the sanitary drainage system for treatment and protection of the environment and waterways. Purified steam (i.e. humidification) shall not discharge to the sanitary drainage system

Secondary (Overflow) Roof Drainage. Secondary (overflow) roof drainage shall be accomplished by sidewall scuppers, scupper drains, or a secondary (overflow) roof drainage system. Secondary (overflow) roof drains shall be the same as roof drains except with integral standpipe or damming weir extension 3-inches above the waterproofing membrane and located within 5-feet of (adjacent to) the primary roof drain, and extended to discharge above grade. Termination above grade shall include a concealed elastomeric pinch valve or similar for rodent proofing, near the discharge, and finished discharge in high finish areas. Discharge shall be in a non-occupied, non-pedestrian area that permits drainage away from the building and pedestrian access.

Rainwater Drainage Equipment

Sand/Oil Separator. Floor drains and/or trench drains in vehicle parking structures and parking garages shall discharge to a sand/oil interceptor prior to discharge to the storm sewer.

Plumbing Fixtures

General. Provide all code, user, occupancy, safety, and emergency required plumbing fixtures, including those indicated in the U.S. Courts Design Guide. Plumbing fixtures shall be manufactured by companies that are approved by the General Services Administration or their representatives and compliant with code and state requirements. All plumbing fixtures shall have motion/user sensing devices (with manual by-pass) for fixture operation and shall be water conserving/saving type fixtures, faucets, and valves.

Plumbing fixture accessibility clearances, installation, and accessories shall be compliant with the Americans with Disabilities Act; Americans with Disabilities Act Accessibility Guidelines (latest edition); and the Uniform Federal Accessibility Standard (latest edition).

Plumbing fixture and accessory support shall be compliant with code, state requirements, ADA/ADAAG, UFAS, and manufacturers requirements.

Natural Gas Systems

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 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 (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 (which could result in an explosion).

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 CO_2 monitoring and alarms. 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. Diaphragms and regulators in gas piping must be vented to the outdoors. There shall be no gas valves (concealed or accessible) permitted above ceilings.

Fuel Oil Systems

Fuel Oil Piping. Fuel oil piping systems shall be double-wall 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 grade 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.

Underground Fuel Oil Storage Tanks (UST). Underground fuel oil storage tanks (UST) shall be of double-wall non-metallic construction, or contained in lined vaults to prevent environmental contamination. Tanks 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 such as border stations). A monitored and alarmed liquid and vapor leak detection system shall be provided in interstitial space of underground tanks, above ground day-tanks, and piping. The installation must comply with local, State and Federal requirements, as well as EPA 40, *CFR 280* and *281*.

5.19 Alterations in Existing Buildings and Historic Structures

The goal of alteration projects is to meet the same standards described in this document for new projects. Equipment/systems that are beyond their useful service lives must be demolished and new systems designed to meet the current usage of the facility. Renovation and rehabilitation designs must satisfy the immediate occupancy needs and anticipate additional future changes. Remodeling shall make building systems become more flexible, not less. Parameters of reuse and disruption of service must be clearly specified in construction documents.

Alteration projects can occur on three basic scales: refurbishment of an area within a building, such as a floor or a suite; major renovation of an entire structure; and up-grade/restoration of historic structures.

In the first instance, refurbishment of an area within a building, the aim shall be to satisfy the new requirements within the parameters and constraints of the existing systems. The smaller the area in comparison to the overall building, the fewer changes to existing systems shall be attempted.

In the second case, major renovation of an entire structure, the engineer has the opportunity to design major upgrades into the mechanical, electrical and communications systems. The mechanical services can come close to systems that would be designed for a new building, within the obvious limits of available physical space and structural capacity.

In the third instance, where a historic structure is to be altered, special documents shall be provided by GSA to help guide the design of the alterations. The most important of these is the HBPP that identifies zones of architectural importance, specific character-defining elements that shall be preserved, and standards to be employed. See Chapter 1: *General Requirements, General Design Philosophy, Historic Buildings*.

When a system is designed, it is important to anticipate how it will be installed, how damage to historic materials can be minimized, and how visible the new mechanical system will be within the restored or rehabilitated space.

The following guidelines shall be followed for HVAC work in historic buildings:

- Design HVAC systems to avoid impacting other systems and historic finishes, elements and spaces.
- Place exterior equipment where it is not visible. Recess equipment from the edge of the roof to minimize visibility of the equipment from grade. Alternatively, explore creating a vault for easier access to large mechanical equipment. If equipment cannot be concealed, specify equipment housings in a color that will blend with the historic face. As a last resort, enclose equipment in screening designed to blend visually with the facade.
- Locate equipment with particular care for weight and vibration on older building materials. These materials cannot accept the same stress as when the equipment is used in newer construction.
- If new ceilings must be installed, insure that they do not block any light from the top of existing windows or alter the appearance of the building from the outdoors. Original plaster ceilings in significant spaces such as lobbies and corridors shall be retained, to the extent possible, and modified only as necessary to accommodate horizontal distribution. Use soffits and false beams where necessary to minimize alteration of overall ceiling heights.
- In buildings containing ornamental or inaccessible ceilings, piping and ductwork shall have to be routed in furred wall space or exposed in the occupiable building area. Exposed ducts must be designed to complement the building architecture in forms and materials used. Use of exposed ducts is encouraged in locations where concealing ducts would obscure significant architectural surfaces or details, such as vaulted ceilings. Exposed ducts shall also be considered in historic industrial buildings and open plan, tall ceiling, high window spaces suited to flexible grid/flexible density treatments.
- If new vertical air distribution risers are required, they shall preferably be located adjacent to existing shafts.
- Reduce heating and cooling loads to minimize size and other impacts of modern equipment.
- Calculate the effect of historic building features such as wall thickness, skylights, and porticos, interior design features such as draperies, shutters and window shades, and existing site features such as landscaping.
- Select system types, components, and placement to minimize alteration of significant spaces. In previously altered spaces, design systems to allow historic surfaces, ceiling heights, and configurations to be restored. Reuse of HVAC system elements is only permitted with written documentation obtained from GSA Property Management by the A/E.

- Retain decorative elements of historic systems where possible. Ornamental grilles and radiators and other decorative elements shall be retained in place.
- Retain the original type of system where a new one cannot be totally concealed. For example, reuse existing radiators with new distribution piping or replace with modern heating-cooling units, rather than adding another type of system that would require the addition of new ceilings or other non-original elements.
- To the greatest extent possible, insure that space is available to maintain and replace equipment without damaging significant features, selecting components that can be installed without dismantling window or door openings.
- Use custom rather than standard commercial products where elements are exposed in formal areas.
- Select temperature and humidity conditions that do not accelerate deterioration of building materials.
- Where equipment is near significant features, insure that leakage from pipes and HVAC units does not cause deterioration. Use deeper condensate drain pans, lined chases and leak detectors.