Mechanical Engineering

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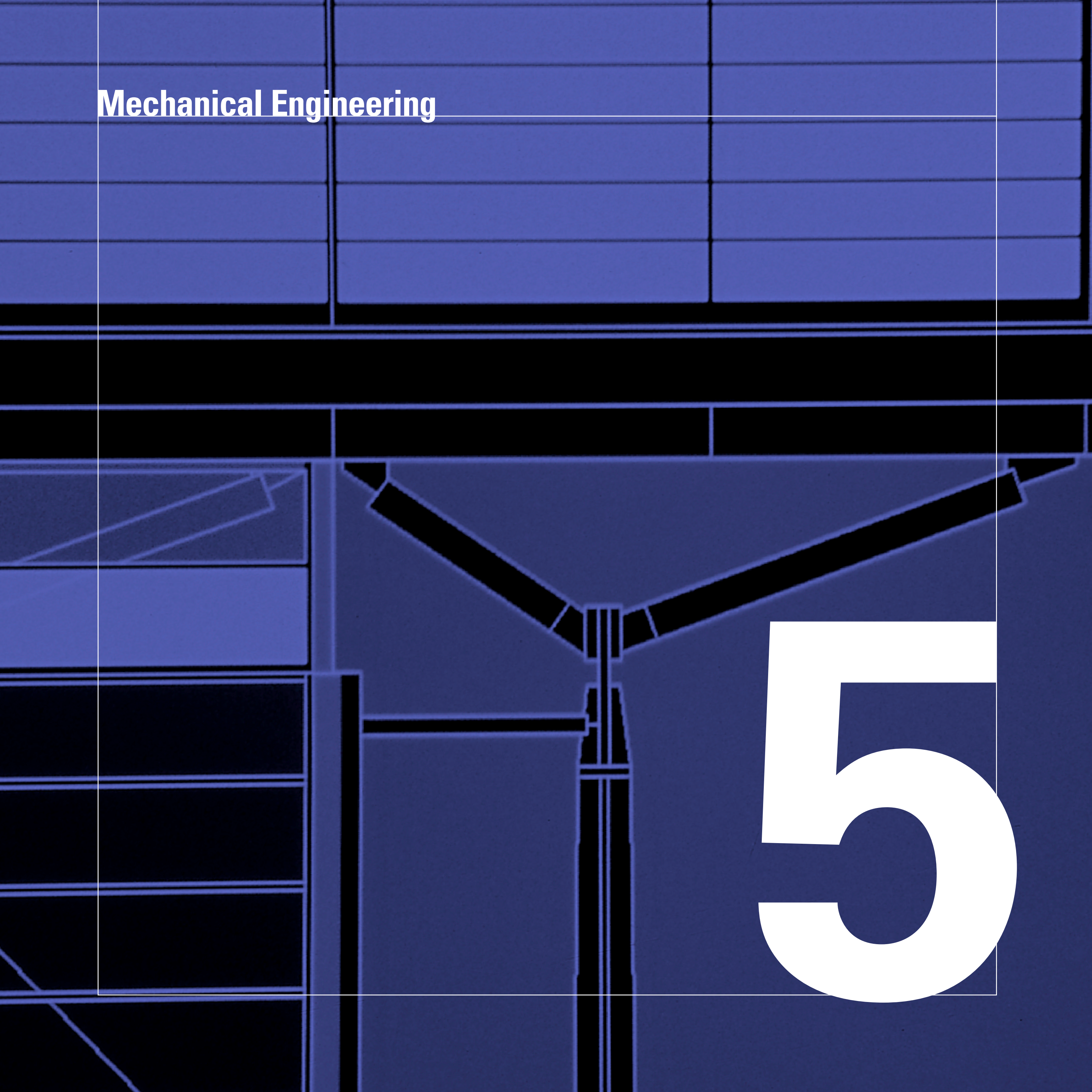

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5.1 General Requirements

The heating, ventilating, and air-conditioning (HVAC) and plumbing systems shall be selected for long-term durability, energy efficiency, flexibility, accessibility, redundancy, ease of operation and maintenance, and efficient life cycle owning and operating costs.

Mechanical systems shall be specifically designed to support all known occupancies and modes of operation, but shall also accommodate planned future occupancies and modes of operation. (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 reverting Courtroom facilities for other Agencies' use).

Maintainability and reliability are major concerns in the operation of Federal buildings. As such, the design and installation for all mechanical equipment and components shall allow for ease of removal and replacement, including major equipment such as boilers, chillers, cooling towers, pumps and air-handling equipment. Vehicular access to mechanical equipment areas shall be provided to facilitate off-site and on-site movement of all major system components.

Sufficient redundancies shall be designed into mechanical systems, enabling continuous services during repair or replacement of a failed piece of equipment or component. Redundant equipment shall not be designed into systems as "stand-by" units but rather shall be used as part of the operating system with equal time cycling through automatic control sequencing.

Proposed systems and equipment will be evaluated for their offerings of advanced technology; however, GSA does not allow the use of experimental, unproven 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.

Mechanical systems must be coordinated and integrated with the designs of other involved/impacted building systems and features. As addressed in Appendix A.2, mechanical systems shall be adapted to support all performance objectives, typically involving sustainability, workplace performance (productivity), firesafety, security, historic preservation, and improved operations and maintenance.

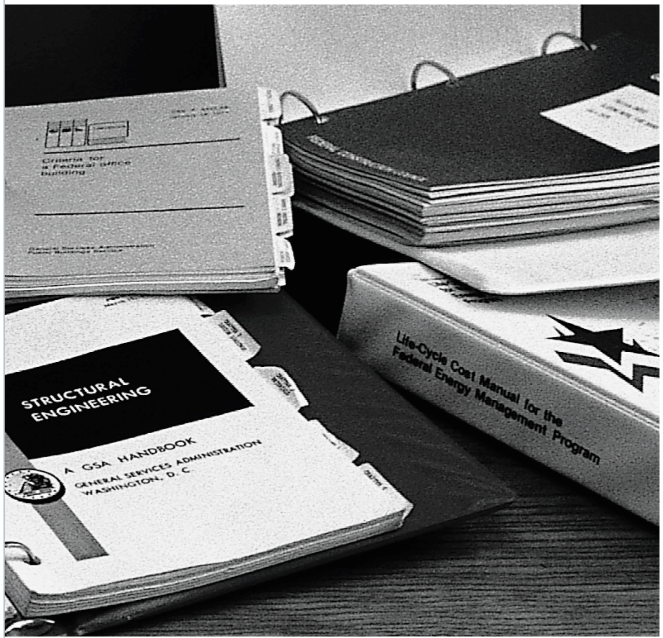
All mechanical systems shall be designed to respond to the local climatic conditions and shall utilize ambient conditions for all possible energy conservation measures while still maintaining desired indoor conditions.

Mechanical systems shall be fitted with automatic controls and devices to assure desired performance in all operating modes. Interface with a Building Automation System shall be as addressed later in this chapter.

Mechanical systems shall generally be selected for lowest life cycle cost, comparing alternatives that meet all required functional objectives. As indicated herein, GSA defined baseline alternatives shall be reflected in these analyses.

Submission requirements are addressed in Appendix A.

5.2 Codes and Standards



As stated in Chapter 1: *General Requirements, Codes and Standards, Building Codes*, facilities should comply with the requirements of site applicable building, mechanical and plumbing codes, including the mechanical and plumbing standards and guidelines referenced therein.

Mechanical Design Standards

The latest editions of the 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. The term "Recommended" as used in the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) Standards shall be considered "Required."

- ASHRAE: *Handbook of Fundamentals.*
- ASHRAE: *Handbook of HVAC Applications.*
- ASHRAE: *Handbook of HVAC Systems and Equipment.*
- ASHRAE: *Standard 15: Safety Code for Mechanical Refrigeration.*
- ASHRAE: *Standard 52: Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter.*
- ASHRAE: Standard 55: *Thermal Environmental Conditions for Human Occupancy.*
- ASHRAE: Standard 62: *Ventilation for Acceptable Indoor Air Quality.*
- ASHRAE: *Standard 90.1: Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings.*
- ASHRAE: *Standard 100.1995: 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&R 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.*
- 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):
  - *HVAC System Duct Design.*
  - *HVAC Duct Construction Standards: Metal and Flexible.*

- *HVAC Air Duct Leakage Test Manual.*
- *Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems.*
- *Seismic Restraint Manual Guidelines for Mechanical Systems.*

- National Electrical Code.
- Federal Information Processing Standard (FIPS) Standard 175: *Federal Building Standard for Telecommunication Pathways and Spaces.*
- All site-specific codes.

Energy and Water Conservation - Life Cycle Costing

Mechanical systems shall be selected to achieve cost effective attainment of "Energy Conservation Standards," addressed within Chapter 1.

Energy and water conservation measures involving mechanical systems must be effectively integrated with other building systems. In particular, energy and water use needs/loads must first be minimized.

Consideration of an Energy Savings Performance Contract (ESPC) for any authorized prospectus level project requires written notification to the Office of the Chief Architect of GSA and the Office of Portfolio Management. All ESPCs shall maintain design control conditions of temperature, humidity, ventilation, acoustics, and other design parameters, for all modes of operation.

Analyses of energy-conserving designs shall include all relevant effects of the building envelope, lighting energy input, domestic water heating, efficient use of local ambient weather conditions, building zoning, efficient part load performance of all major HVAC equipment and the ability of involved building automation equipment to automatically adjust for building partial occupancies, optimized start-stop times and systems resets.

Water conservation shall be a requirement of all mechanical systems design. All water cooled mechanical equipment shall be provided with a recirculating cooling water system and water to air heat rejection equipment (e.g. cooling towers, fluid coolers) shall have drift eliminators (and shall be designed with indoor retention tanks to minimize evaporative losses and eliminate the need of basin heaters for facilities in northern climates). No domestic water-cooled system that results in water wasting is allowed.

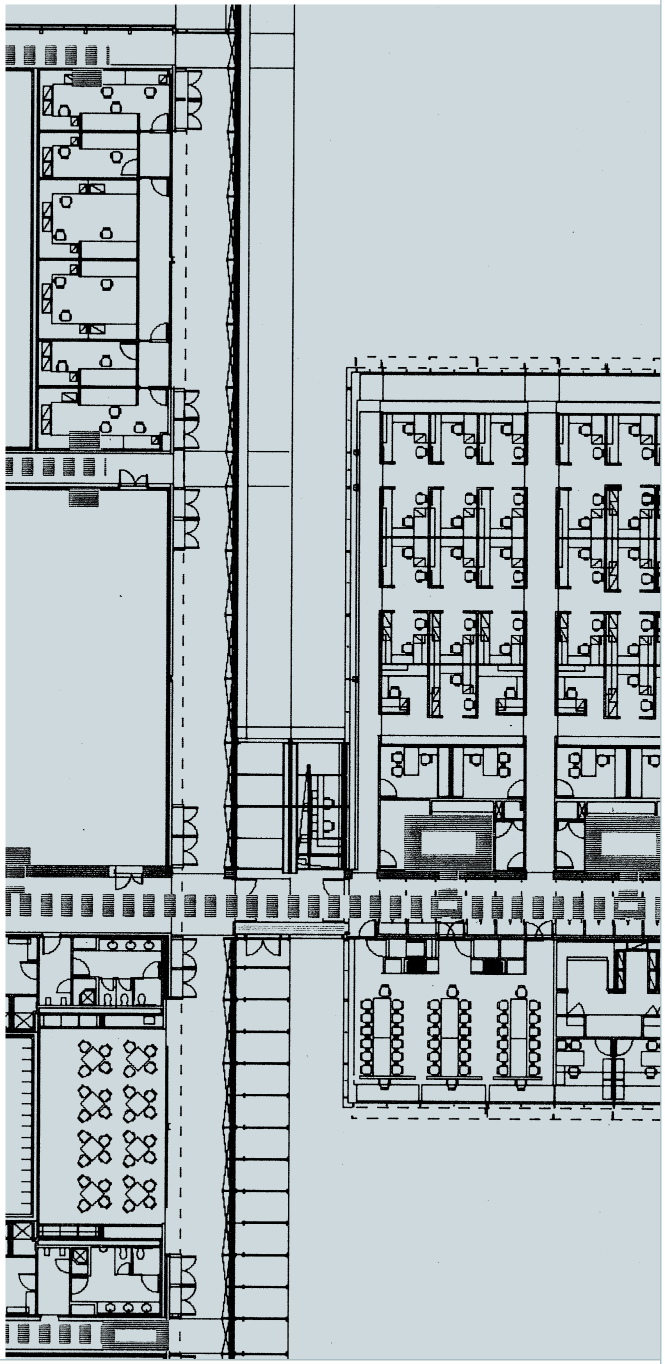
HVAC system designs shall include a life cycle cost analysis of a described baseline plus a minimum of two GSA-approved alternate HVAC systems. For new construction, one HVAC alternative shall utilize a renewable energy source, and one shall be appropriate for the particular site conditions (e.g. if district steam or chilled water is available).

Life cycle cost submittals must utilize the computer program entitled *Building Life Cycle Cost*, latest version. As addressed in Chapter 1: *General Requirements*, this program is available from NIST free of charge via the Internet.

Reference should also be made to the *Life Cycle Costing Manual for the Federal Energy Management Program (NIST Handbook 135) and Energy Prices* and *Discount Factors for Life Cycle Cost Analysis*, both of which are available through the Internet.

The period over which the costs must be calculated will typically be 25 years. The design/construction period is not to be included in this 25 years. The life cycle cost analysis must include investment costs, energy costs, non-fuel operation and maintenance costs, repair and replacement costs, and salvage values. The submittal must utilize the subprogram *Federal Analysis-Projects Subject to OMB's A-94 Guidelines*. There is no need to break down the facility into component parts. The disk has a users guide and reference manual which can be printed out. For the purpose of computing energy requirements, the submittal shall assume the building shall operate under the occupied cycle from 6:00 a.m. to 6:00 p.m. Monday through Friday for every week of the year. Holiday schedule, occasional extended hours of operation or special areas requiring 24 hours per day, every day, shall not be considered as variables to the 60 hours per week occupancy. For operations and maintenance personnel costs (i.e. labor rates or employee burden cost), use a local rate, including fringes.

The baseline HVAC system described in the following section indicates an acceptable system and sets the reference from which advantages and disadvantages of other systems can be compared through the life cycle cost analysis.



5.3 Baseline HVAC System

General. Unless otherwise directed in design programming documents, the following description of a baseline HVAC system shall be used when comparing system alternatives. Refer to the specific sections of this chapter for more detailed information on all HVAC and plumbing system requirements.

Zoning Requirements. Interior control zones shall not exceed 180 m^2 (2000 square feet) for open office areas or a maximum of three offices per zone for closed office areas. Corner offices shall be a dedicated zone. Perimeter zones shall be no more than 4.6 meters (15 feet) from an outside wall along a common exposure. Independent zones shall be provided for spaces such as conference rooms, entrance lobbies, atria, kitchen areas, dining areas, child care centers, physical fitness areas, and courtrooms.

Separate systems shall be provided for buildings where perimeter zones have heating and/or cooling loads very different from interior zones.

Large air-handling units serving multiple floors for buildings with scattered loads after normal office hours is not acceptable. Multiple air-handlers or floor-by-floor systems shall be considered as baseline. For federal courthouses no more than two courtrooms shall be served by any single air-handling unit, with that air-handling unit dedicated to serve those courtrooms. Separate piping loops and systems shall be used for off-hours systems.

The supply of zone cooling and heating shall be sequenced to prevent (or at the very least, minimize) the simultaneous operation of heating and cooling systems for the same zone. Supply air temperature reset control shall be utilized to extend economizer operations and to reduce the magnitude of reheating, recooling or mixing of supply air streams.

Hot Water Heating Systems and Equipment. The baseline heating system shall be comprised of dual fueled natural gas and fuel oil boilers producing low temperature heating hot water at 205 kPa (30psi) working pressure and a maximum heating hot water temperature of 120°C (250°F). For northern climates, a minimum of three equally sized units shall be provided, with all three units having sufficient combined capacity to satisfy 120 percent of the total peak load of heating and humidification requirements. For southern climates, a minimum of two equally sized units at 67 percent of the peak capacity (each) shall be provided. The units shall be packaged with all components and controls factory pre-assembled.

All required auxiliaries for the boiler system shall be provided, including expansion tanks, heat exchangers, water treatment, and air separators, as required. Pressurized diaphragm expansion tanks shall be considered baseline. Pumps shall be centrifugal type and shall generally be selected to operate at 1750 RPM.

A primary-secondary piping arrangement with a modulating mixing control valve and higher primary flow rate shall be provided to assure that the boiler return water temperature does not drop too low, as commonly occurs with night setback. The baseline system shall utilize parallel piping systems with a two-pipe main distribution system arranged in a reverse return configuration.

The baseline system utilizes a dedicated hydronic heating system with convectors to offset heat losses through the building envelope in perimeter zones.

Materials acceptable for piping systems are black steel and copper. (No PVC or other types of plastic pipe are permitted.) Dielectric unions shall be provided between ferrous and copper-based materials (or other dissimilar metals). All piping systems must be insulated in accordance with ASHRAE Standard 90.1. Piping systems conveying fluids, those having design temperatures less than 18°C (65°F) or greater than 40°C (105°F), shall be insulated.

Cooling Systems and Equipment. The baseline cooling system shall be comprised of electric-powered water-cooled chilled water-generating equipment producing chilled water at a design supply temperature between 4°C and 7°C (40°F and 44°F) and a temperature differential of 7°C (12°F). When the peak cooling load is 1760 kw (500 tons) or more, a minimum of three equally sized units shall be provided with all three units having sufficient combined capacity to satisfy 120 percent of the total peak cooling load. If the peak cooling load is less than 1760 kw (500 tons), a minimum of two equally sized machines shall be provided, each at 67 percent of the peak load.

All required auxiliaries for the chiller systems shall be provided, including expansion tanks, heat exchangers, water treatment, and air separators, as required. No chlorofluorocarbon (CFC) refrigerants are permitted in new chillers.

Induced draft cooling towers with multiple-speed or variable speed condenser fan controls shall be considered baseline. The number of cells shall match the number of chillers. Cooling towers shall be constructed of corrosion-resistant materials (stainless steel, fiberglass and PVC) particularly in coastal areas, and for tower components that are typically wet in the normal operation of the tower.

Pumps shall be 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 separate pump shall be designed for each condenser water circuit. Variable volume pumping systems should be considered for all secondary piping systems with pump horsepower greater than 10 kW (15 HP). The specified pump motors shall not overload the entire range of the pump curve.

A primary/secondary chilled water pumping and piping arrangement shall be considered as baseline, with constant volume primary pumping and variable volume secondary pumping. The primary and secondary circuits shall be separate, with neither having an effect on the pumping head of the other. The primary circuit serves the source equipment (chillers), while the secondary circuit serves the load. The baseline system shall utilize parallel piping systems with a two-pipe main distribution system arranged in a reverse return configuration.

Materials acceptable for piping systems are black steel and copper. Dielectric unions shall be provided between ferrous and copper-based materials (or other dissimilar materials). All piping systems must be insulated in accordance with ASHRAE Standard 90.1. Piping systems conveying fluids, those having design temperatures less than 18°C (65°F) or greater than 40°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 to whether piping is concealed or exposed. Chilled water piping systems shall be insulated with non-permeable insulation (of perm rating 0.00) such as cellular glass.

Air Distribution Systems and Equipment. The baseline air-handling system is a simple VAV system providing cooling only. Any heating requirement (except freeze protection) shall be handled by a separate, dedicated perimeter system. The VAV supply fan shall be designed for the largest block load, not the sum of the individual peaks. Refer to *HVAC System Components and Air Distribution Systems* sections later in this chapter for detailed requirement.

The baseline air-handling units shall be sized not to exceed 12.1 m^3/s (25,000 cfm) per air-handling unit. Casings and coils of air-handling units shall be sized so that the volume capacity can be increased in the future by 10 percent by replacing the fan. Speed control shall be achieved via variable speed drives. Air supply temperature (at the discharge of the cooling coil) shall not be below 11.7°C (53°F).

In buildings without operable windows, air handling/ventilation systems shall involve controls/devices to assure outdoor air exchange rates shall be in accordance with ASHRAE Standard 62.

Individual finned tube coils shall be between six and eight rows and at least 2.1 mm between fins (12 fins per inch) to ensure coil cleanability.

Refer to *HVAC System Components, Drains and Drain Pans* later in this chapter for drain requirements. Ultra-violet light (C band) emitters shall be incorporated down-stream of all cooling coils and above all drain pans to control airborne and surface microbial growth and transfer.

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. Pre-filters shall be 30 percent to 35 percent efficient. Final filters shall be 80 percent to 85 percent efficient for particles at 3 microns.

Fans shall be selected on the basis of 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 operation curve. The fan and fan motor shall be internally mounted and isolated on a full-width isolator support frame using isolation springs.

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 should be provided in ventilation equipment, ductwork and plenums as required for inspection and cleaning.

The baseline air-handling system shall incorporate an air-side dry bulb economizer.

Terminals shall be designed for their specific location. For new construction, manually adjustable floor terminals shall be provided for raised floor plenum distribution. For repair and alterations involving ceiling distributions, VAV terminals shall be pressure-independent type units, specifically designed for VAV air distribution.

For raised floor applications, provide a dedicated outside air ventilation/distribution system, effectively limiting outside air interface of central air-conditioning units to only economizer cycle operations.

Supply and return air ducts shall be designed and constructed to allow no more than 3 percent leakage of total airflow in systems up to 750 Pa (3 inches WG). In systems from 751 Pa (3.1 inches WG) through 2500 Pa (10.0 inches WG) ducts shall be designed and constructed to limit leakage to 0.5 percent of the total air flow. Generally, ductwork shall be fabricated from galvanized sheet metal, in accordance with SMACNA guidelines.

All supply air ducts shall be externally insulated, in accordance with ASHRAE Standard 90.1. Supply air duct insulation shall have a vapor barrier jacket. Internal duct lining is not acceptable. Refer to *HVAC System Components, Insulation* section later in this chapter for detailed requirements.

Sound and Vibration. The baseline system shall include sound and vibration provisions that have given appropriate consideration to airborne equipment noise, equipment vibration, ductborne fan noise, duct breakout noise, air flow generated noise, duct borne crosstalk noise and structure borne vibration.

HVAC Controls and Instrumentation. A Direct Digital Control (DDC) system with host computer remote monitoring and control shall be considered as baseline. Minimum control and monitoring points for typical HVAC equipment as listed in Table 5-6 of this chapter shall be provided, along with all associated instrumentation. Refer to *Meters, Gauges, and Flow Measuring Devices* section later in this chapter for detailed requirements on instrumentation.

Building Automation System (BAS). A computer based BAS shall be provided as part of the baseline system. Refer to the BAS section later in this chapter for specific requirements.

5.4 Heating, Ventilating, and Air-Conditioning (HVAC)

General Parameters

HVAC system parameters are provided here for reference, but specific energy performance directives are also listed in CFR 10-435. Compliance with the latest versions of ASHRAE Standard 90.1 and ASHRAE Standard 62 is required for the elements of the project (architectural, mechanical, and electrical).

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-percent column dry-bulb temperature in the ASHRAE Fundamentals Volume. Summer design conditions shall be based on the 0.4-percent column dry-bulb temperature with its corresponding mean coincident wet-bulb temperature.

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

The following spaces 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. The air from these spaces must be exhausted directly to the outdoors at 100 percent.

Table 5-1
Indoor Design Conditions[3]

Type of Area	Summer DB[1]	Summer RH[2]	Winter[8] DB[1]	Winter RH[2]
General Office	24 (75)		22 (72)	30[12]
ADP Rooms[9]	22 (72)	45[4]	22 (72)	45[4]
Corridors	24 (75)		22 (72)	
Building Lobbies	24 (75)		22 (72)	
Toilets	24 (75)		22 (72)	
Locker Rooms	26 (78)		21 (70)	
Electrical Closets	26 (78)		13 (55)	
Tunnels, Bridges	24 (75)		22 (72)	
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)	30[12]

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.

Table 5-2
Air Intake Minimum Separation Distances

Object	Minimum Distance m	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

* Intakes for roofs must be at least 0.2 m (8 inches) above the average maximum snow depth and consider the potential for drifts at the intake location. 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.

Indoor Air Quality

When a building is new, volatile compounds (VOC) can be released in large quantities from materials, such as adhesives, vinyl and carpets. A purge cycle of 100 percent outside air is recommended to run for several days prior to occupancy and at late evening/early morning to purge VOC build-up during the first weeks of occupancy.

GSA recognizes the importance of adequate ventilation to maintain indoor air quality. The outside air and 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 within 90% of required levels 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.

Dilution with outside air is the primary method of maintaining acceptable indoor air quality. The site shall be surveyed to determine if there are sources of contaminants that may be unacceptable for use indoors with respect to odor and sensory irritation. The location of outside air intakes must be carefully evaluated to avoid intake of outside pollutants, such as contamination by car and truck emissions or by other equipment, and short-circuiting of building exhaust. Outdoor intakes should be located with consideration of the distances listed in Table 5-2, except in consideration of air borne security where intakes shall be elevated to roof levels or well above pedestrian access.

Internal Heat Gain

Occupancy Levels. For office spaces, the average density of the *occupiable floor area* of a GSA building is one person per 9.3 square meters (100 square feet). Within areas occupied by work stations, the occupancy load can be as dense as one person per 7 square meters (75 square feet) in local areas. Block loads and room loads should be calculated accordingly. Sensible and latent loads per person should be based on the latest edition the ASHRAE *Handbook of Fundamentals*.

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

Equipment Densities. Internal heat gain from all appliances—electrical, gas, or steam—should be taken into account. When available, manufacturer provided heat gain and usage schedules should be utilized to determine the block and peak cooling loads. Typical rate of heat gain from selected office equipment should be based on the latest edition of the ASHRAE *Handbook of Fundamentals*. The cooling load estimated for the connected electrical load should be based on the electrical load analysis, and the minimum connected receptacle load outline in Chapter 6: *Electrical Engineering, Electrical Load Analysis*, and anticipated needs of GSA's Office of Chief Information officer.

Lighting Levels. For preliminary design loads, heat gain from lighting levels described in Chapter 6: *Electrical Engineering, Lighting, Interior Lighting, Illumination Levels* shall be used.

If a building program shows an office building with 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 will be occupied by closed offices at some point in the future. Internal heat gains shall be designed to adapt.

Acoustical Requirements

See Section *Vibration Isolation, Acoustical Isolation, and Seismic Design for Mechanical Spaces* of this chapter. Acoustical criteria for all building spaces are described in Chapter 3: *Architectural and Interior Design, Special Design Considerations, Acoustics.*

Zoning Criteria for HVAC Systems

Interior control zones must not exceed 180 m^2 (2000 square feet) per zone for open office areas or a maximum of three offices per zone for closed office areas. Corner offices shall be a dedicated zone. Perimeter zones shall be no more than 4.7 meters (15 feet) from an outside wall along a common exposure. Independent zones should be provided for spaces such as conference rooms, entrance lobbies, atria, kitchen areas, dining areas, child care centers and physical fitness areas.

If a building program shows that an office building will 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 will be occupied by closed offices at some point in the future. Zoning should be designed to adapt.

Separate systems shall be provided for buildings where perimeter zones have heating and/or cooling loads very different from interior zones.

Large air-handling units serving multiple floors for buildings with scattered loads after normal office hours is not acceptable to GSA. Multiple air-handlers or floor-by-floor systems shall be used. AHU's are not permitted for air delivery capacity greater than 12.1m^3/s (25,000 cfm). Courtrooms shall be provided with dedicated air-handling units, with each unit serving no more than two courtrooms. Separate piping loops and systems shall be used for off-hours systems.

The supply of zone cooling and heating shall be sequenced to prevent (or at the very least, minimize) the simultaneous operation of heating and cooling systems for the same zone. Supply air temperature reset control shall be utilized to extend economizer operations and to reduce the magnitude of reheating, recooling or mixing of supply air streams.

HVAC System Components

AHU's. Air supply temperatures (at the discharge of the cooling coil) shall not be below 11.7°C (53°F).

Coils. Individual finned tube coils should generally be between six and eight rows with at least 2.1 mm between fins (12 fins per inch) to ensure coil cleanability. Dehumidifying coils shall be selected for no more than negligible water droplet carryover beyond the drain pan at design conditions. Equipment and other obstructions in the air stream shall be located sufficiently downstream of the coil that it will not come in contact with the water droplet carryover. Cooling coils shall be selected at or below 2.5 m/s face velocity (500 fpm) to minimize moisture carryover. Heating coils shall be selected at or below 3.8 m/s face velocity (750 fpm).

Drains and Drain Pans. Drain pans located in supply air ducts, plenums, air-handling units, and fan coil units shall be 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 or greater than the design static pressure. Ultraviolet light (C band) emitters shall be incorporated downstream of all cooling coils and above all drain pans to control airborne and surface microbial growth and transfer.

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 should be provided in ventilation equipment, ductwork and plenums as required for in-situ inspection and cleaning. Equipment access doors or panels should be readily operable and sized to allow full access. Large central equipment shall be situated to facilitate its replacement.

In addition, adequate methods of access shall be included for items such as: chillers; boilers; heat exchangers; cooling towers; reheat coils; VAV boxes; pumps; hot water heaters; and all devices which have maintenance service requirements.

Access to elevated major equipment (such as AHU's, cooling towers, chillers, and boilers) must be by stairs, not by ladders.

Humidifiers, Air Washers, and Direct Evaporative Coolers. Make-up water for direct evaporation humidifiers, air washers, direct evaporative coolers, or other water spray systems shall originate directly from a potable source or from a source that has equal or better water quality with respect to both chemical and microbial contaminants. Humidifiers and water spray systems shall be designed so that microbiocidal chemicals or water treatment additives are not emitted in ventilation air unless they are registered for this application.

Insulation. All insulation materials 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 fire and smoke hazard ratings.

Materials used as internal insulation exposed to the air stream in ducts shall be in accordance with UL 181 or ASTM C 1071 erosion tests, and shall not promote or support the growth of fungi or bacteria, in accordance with UL 181 and ASTM G21 and G22. Internal duct lining shall only be used for courtroom return air transfer grilles, and only if required for acoustic purposes.

Insulation shall be provided on all cold surface mechanical systems, such as ductwork and piping, where condensation has the potential of forming and 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).

Sizing and Selection Standards for Equipment and Systems. Mechanical components for HVAC systems shall be sized and selected to satisfy the heating and cooling loads determined by the building thermal performance analysis and within the requirements provided in the latest version of ASHRAE Standard 90.1 and ASHRAE *HVAC Systems and Equipment Handbook*.

Special Mechanical Requirements for Building Spaces

Entrance Vestibules. Sufficient heating and cooling should be provided to offset the infiltration load of the space. The entrance vestibule should be positively pressurized relative to atmospheric pressure to minimize infiltration.

Mechanical Rooms. All mechanical rooms must be mechanically ventilated. Mechanical ventilation shall be sufficient to maintain room space conditions as indicated in Table 5-1. Water lines shall not be located above motor control centers or disconnect switches and shall comply with requirements of NEC 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.

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.

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 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 efficiently and economically. The operation of the kitchen exhaust systems should not effect the pressure relation between the kitchen and surrounding spaces.

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

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.

United States Courthouse, White Plains, NY

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 outdoors. Refer also to requirements of USMS Publication 64.

Firing Range. Special HVAC considerations will 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 participant 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 gun powder residue into the atmosphere. Discharge of firing range exhaust air to outdoors shall be carefully located to prevent recirculation into the outside air intake of any HVAC system. Firing ranges shall be capable of continuous, isolated from other building systems.

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 electric generating system and sufficient heating capacity to maintain space temperature of 21°C (70°F) with design winter outdoor temperature.

Electrical Equipment Rooms. No water lines are permitted in electrical rooms, except as associated with fire protection.

Communications Closets. Communications closets must be ventilated and cooled like offices. Communications closets shall meet the requirements of EIA/TIA Standard 569. Closets which house critical communications components shall be provided with dedicated air-conditioning systems which can operate on the emergency power circuit.

Elevator Machine Rooms. In climates where heating and/or cooling of the elevator machine room is required, ventilation louvers shall be equipped with motorized dampers (normally open) that close when the heating or cooling system is in operation and that open when the fire alarm is actuated. Cooling or heating must be provided to maintain room conditions required by equipment specifications, and in accordance with Table 5-1 of this chapter.

Emergency Generator Rooms. The environmental systems shall meet the requirements of NPPA 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 air supply and exhaust shall be located so air does not short circuit. Generator exhaust should 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 is least desired.

UPS Battery Rooms. Battery rooms must be equipped with eye wash, emergency showers and floor drains. 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 circuit. Fans shall be spark- resistant, explosion proof, with motor outside the air stream, ductwork to be negative pressure system of corrosion-resistant material, with exhaust directly to outdoors in a dedicated system.

Loading Docks. Outside air intakes must not be located near loading docks. The entrances and exits at loading docks and service entrances shall be provided with a positive means to reduce infiltration and outside debris.

24-Hour Spaces. Spaces that have requirements for environment condition maintenance at continuous times shall be supplied from independent systems. All areas designated for the housing of computer-based central processing of the Fire Alarm Monitor and Control System, the Security Monitor and Control Systems and the BAS shall be provided with HVAC systems to maintain temperature and humidity requirements at all times regardless of building occupancy.

Miscellaneous. Refer to Chapter 7: *Fire Protection Engineering*, for smoke control requirements.

Placing Mechanical Systems in Buildings

In order to achieve system flexibility and thorough integration between building architecture and engineering systems, **a concept for the distribution of mechanical systems must be established during the architectural schematic design**. The locations of vertical and horizontal mechanical elements should be established before the architectural concept is finalized. The structural design must be sufficiently developed in order to incorporate structural components' depth and width in the sizing of vertical and horizontal chases, to minimize the core drilling and sleeving of critical structural members, and to provide sufficient plenum height for the mechanical, plumbing, fire protection and electrical systems.

Planning Grid, Floor Grid, and Ceiling Grid. A common planning module is to be used. The relationship of this module to wall placement, ceiling grids, and location of mechanical and electrical elements is described in detail in Chapter 3: *Architectural and Interior Design, Building Planning, Planning Module, Floor-to-Floor Heights and Vertical Building Zoning* and *Space Planning, Office Space, Floor and Ceiling Grids*. Mechanical elements on floors and in ceilings—equipment, air diffusers, air distribution ducts and branch sprinkler piping—are given measurable locations. Supply air devices for perimeter zones shall be located within 1.5 meters (5 feet) of the outside wall.

Horizontal Distribution of HVAC Elements. Ceiling diffusers shall be located within the ceiling framing. If slot diffusers are used, as in integrated architectural ceilings, they can be placed on the grid line. Experience has shown that a staggered diffuser layout in a uniform pattern adapts most easily to future changes in wall configurations.

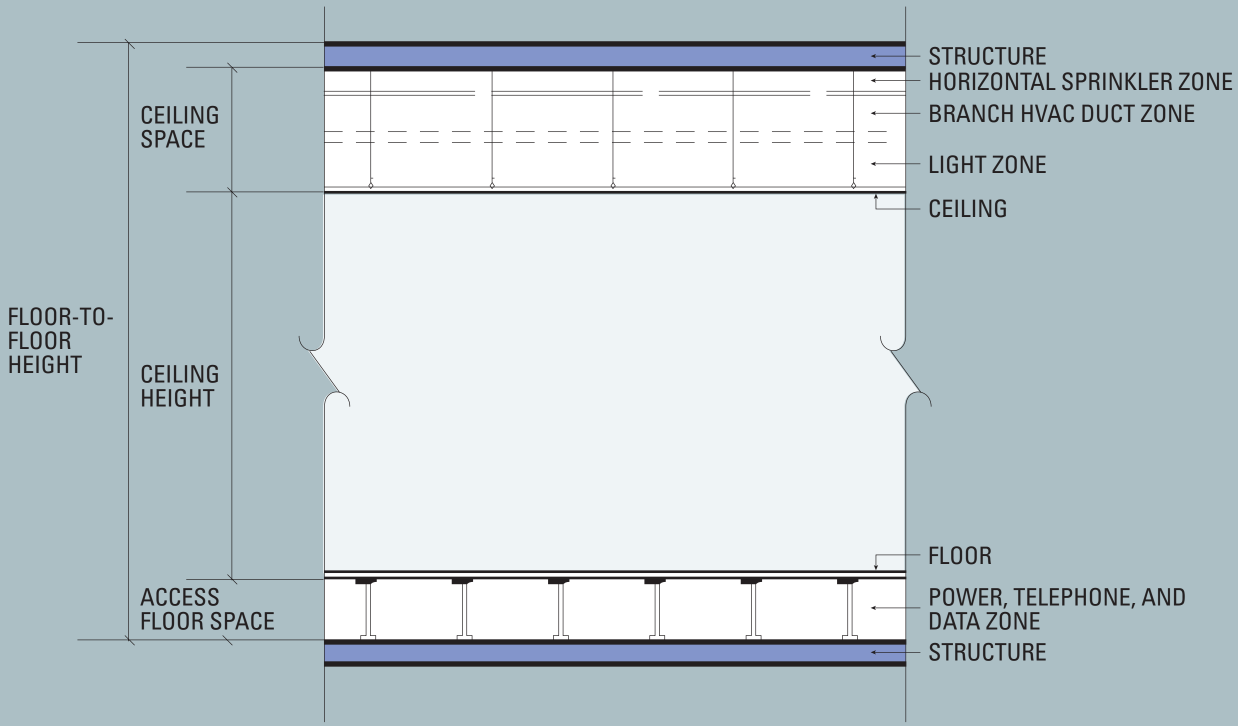
Vertical Zoning of Ceiling Plenum Space. The ceiling plenum must be laid out to provide distinct zones for the placement of different utilities (see Figure 5-1). The depth of the ceiling plenum and floor space must be determined early in the design, in order to arrive at the necessary floor-to-floor height of the building.

To the maximum extent possible, each mechanical system shall be given a distinct horizontal layer in the available ceiling plenum space. As practical, the systems should be routed within these designated zones. Adherence to the horizontal layering system will aid in the coordination between trades in the field and to accommodate future modifications to systems without moving other components. The pressured piping systems, domestic water supply and the sprinkler piping should be located in the highest zone, 150 mm to 200 mm (first 6 to 8 inches), near the underside of the structure, or possibly through it if steel joists are used. The lighting systems should be provided with a zone, 200 mm to 255 mm (8 to 10 inches), immediately above the ceiling level. The HVAC ductwork (supply, return and exhaust) should be layered in a middle zone below the pressure piping zone and above the lighting zone. Gravity systems, sanitary and storm drainage must be coordinated with all three zones so they maintain the proper slope. Power and systems conduit and cable trays also need to be coordinated with all three zones. Hydronic systems shall not be located above power and cable trays and adequate space must be provided to allow access. All piping and ductwork shall be kept out of spaces above electrical rooms, and limited above elevator equipment rooms. Enough space must be left between the HVAC and lighting zones, 150 mm (6 inches), to accommodate future lighting moves and changes without moving other components.

Horizontal routing of major HVAC and plumbing systems shall be kept above the corridors and open spaces. The design and layout of mechanical systems should minimize the maintenance requirements of all items located above private offices, lobbies, conference rooms and ornamental ceilings. As practical, terminal air devices, fan coils, and valves should be located above accessible ceilings and in service areas, such as janitors closets and storage areas. If valves for piping systems and balancing dampers for ducted systems cannot be avoided above inaccessible ceilings, ceiling access panels must be provided at each location.

Routing of ductwork and piping outside of the building exposed to the weather shall be kept to an absolute minimum. Refer to Arrangement of Mechanical Spaces, Roof-Mounted Equipment section of this chapter for additional requirements.

Figure 5-1 Vertical Zoning of Floor-to-Floor Height



Vertical Distribution. Risers for ducts and hydronic piping shall be combined with other core elements to form compact groups and maximize usable floor space. Wet columns (domestic cold water, waste and vent) should be placed in each core and distributed in general office space at a maximum distance of 36 m (120 feet) on center. Ductwork and plumbing piping shall be run in separate chases.

Valves and piping placed in the exterior wall shall be located on the conditioned side of insulation and vapor barrier. Extended runs should be avoided in unheated garage space (except in southern climates).

Gas piping shall not be placed in unventilated spaces, such as trenches or unventilated shafts, where leaking gas could accumulate and explode.

5.5 Arrangement of Mechanical Spaces

Minimum Space Requirements. A minimum of 2 percent the typical floor's gross floor area shall be provided on each floor for air-handling plant. A minimum of 3 percent the typical floor's gross floor area shall be provided for the central heating and cooling plant (location to be agreed). A minimum of the 1.5 percent of the typical floor's gross floor area shall be provided for the cooling system's water-cooled heat rejection equipment (location to be agreed).

Vertical Clearances. Mechanical equipment rooms generally shall have clear ceiling heights of not less than 3.6 m (12 feet). Catwalks shall be provided for all equipment that cannot be maintained from floor level. Where maintenance requires the lifting of heavy parts (90 kg (200 pounds) 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 600 mm (2 feet). Air-handling units require a minimum clearance of 750 mm (2 feet 6 inches) on all sides, except the side where filters and coils are accessed. The clearance on that side should equal the length of the coils plus 600 mm (2 feet). Arrangement of large (over 400 mm (4 feet)) or heavy (over 20 kg (50 lbs.)) equipment shall allow access by cranes or include hoists for repair and maintenance.

Roof-Mounted Equipment. All equipment that is installed above grade, either on a roof or mechanical room, shall be provided with adequate access to the equipment for routine maintenance. Access to above-grade equipment shall be by a permanent means, such as an elevator cab stop, stairway, or ladder. Stairway and ladder access shall be provided with a landing at any access hatchway. All rooftop equipment, except for cooling towers and exhaust fans manufactured for outdoor services, shall be located inside the building or in a penthouse enclosure and protected from the weather to insure that equipment can be properly maintained in inclement weather. Roof access shall be by stair, having approximately 11-inch by 7-inch high treads, not by ladder or steep stairs.

Lighting. Lighting in equipment rooms shall be arranged so as not to interfere with equipment.

Housekeeping Pads. Housekeeping pads shall be at least 75 mm (3 inches) larger than the mounted equipment on all sides and a minimum of 100 mm (4 inches) thick.

Piping. Piping shall be arranged in an orderly fashion, parallel to building lines wherever possible. Access to the underside of the structure should not be completely blocked.

Ductwork. Ductwork shall be arranged with a minimum of bends. Access to piping and the underside of the structure should not be obstructed.

5.6 Heating Systems

College Park, MD

Steam Heating
District steam heating, if available, shall be used for heating if determined to be economical and reliable through a life cycle cost analysis. If steam is furnished to the building, such as under a district heating plan, it should be converted to hot water with a heat exchanger 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.

Hot Water Heating Systems
GSA prefers low-temperature hot-water heating systems; 205 kPa (30 psi) working pressure and maximum temperature limitation of 120°C (200°F). 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*.

Water Treatment. See section *Cooling Systems, Chilled Water Systems, Water Treatment* of this chapter.

Temperature and Pressure Drop. Supply temperatures and the corresponding temperature drops for space heating hot water systems must be set to best suite the equipment being served. Total system temperature drop should not exceed 22°C (40°F). Design water velocity in piping should not exceed 2.5 meters per second (8 feet per second) or design pressure friction loss in piping systems should not exceed 0.4 kPa per meter (4 feet per 100 feet), whichever is larger.

Pump and Piping Systems. The baseline system shall utilize parallel piping systems with a two-pipe main distribution system arranged in a reverse return configuration. Series loop piping for terminal or branch circuits of commercial or institutional systems shall be equipped with automatic flow control valves at terminal units (all types of heat transfer units). Reverse return is considered baseline because it provides the best overall control and maintenance of a balanced system as the system is modified. 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 branches, such as at each floor level, building wing or mechanical room.

Each boiler shall be provided with a control and piping arrangement, which protects the boiler from thermal shock. A primary-secondary piping arrangement with a modulating mixing control valve and higher primary flow rate will assure that the boiler return water temperature does not drop too low, as commonly occurs with night setback. Hydronic hot water space heating pumps should generally be selected to operate at 1750 RPM. Variable volume pumping systems should be considered for all secondary piping systems with pump horsepower greater than 10 kW (15 HP).

Refer also to provisions in *Piping Systems* in this chapter.

Pressurized diaphragm expansion tanks shall be used when available 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.

Freeze Protection. Propylene or ethylene glycol manufactured specifically for HVAC systems shall be used to protect hot water systems from freezing, where extensive runs of piping are exposed to weather, where heating operations are intermittent or where coils are exposed to large volumes of outside air. 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 should 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.

Boilers and Heat Exchangers

Boilers. Boilers for hydronic hot water heating applications shall be 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, with all three units having sufficient combined capacity to satisfy 120 percent of the total peak load of heating and humidification requirements. For southern climates, a minimum of two equally sized units at 67 percent of the peak capacity (each) shall be provided. The units shall be packaged, with all components and controls factory pre-assembled. 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 outside air reset, shall be utilized to maximum efficiency and performance.

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

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

Individual boilers with ratings higher than 29 MW (100 million Btu/hour) or boiler plants with ratings higher than 75 MW (250 million Btu/hour) are subject to review by the Environmental Protection Agency. GSA will coordinate this review.

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.

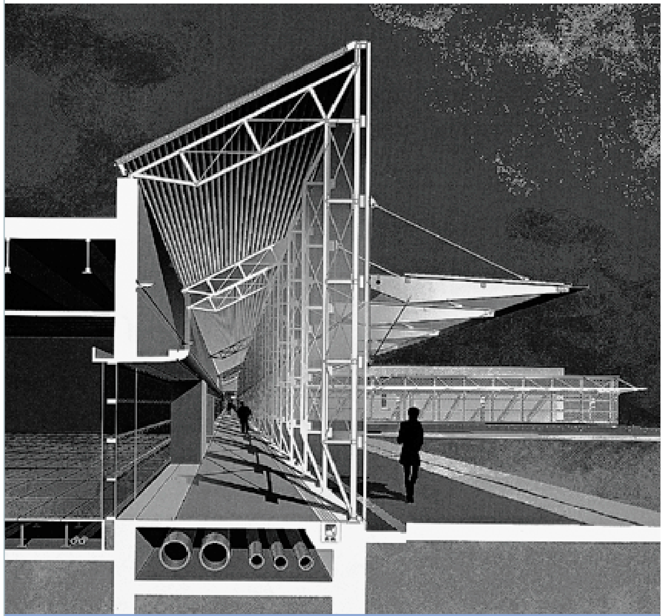
Heat Exchangers. Steam-to-water heat exchangers shall be used in situations where district steam is supplied and a hot water space and domestic hot water heating system have been selected. In high rise buildings, it may be an advantage to create zones by distributing steam vertically and installing several heat exchangers, each serving a number of floors. Double-wall heat exchangers shall be used in domestic hot water heating applications.

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.

5.7 Cooling Systems



U.S. Census Bureau

Chilled Water Systems

Chilled water systems include chillers, chilled water and condenser water pumps, cooling towers, piping and piping specialties.

The chilled water systems shall have a 7°C (12°F) temperature differential, with a design supply water temperature between 4°C and 7°C (40°F and 44°F). In climates with low relative humidity, an 8°C (14°F) differential may be used.

District chilled water, if available, shall be used for cooling only if determined to be economical and reliable through a life cycle cost analysis.

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) should be analyzed. Likewise, the feasibility of gas-engine driven chillers and absorption chillers should be considered.

Microprocessor-based controls shall be used. 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.

Chilled water machines shall be installed in a common mechanical room area. When the peak cooling load is 1760 kw (500 tons) or more, a minimum of three equally sized units shall be provided with all three units having sufficient combined capacity to satisfy 120 percent of the total peak cooling load. 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.

Chillers shall be piped to a common chilled water header with provisions to sequence chillers 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 chiller systems shall be provided with expansion tanks, heat exchangers, water treatment and air separators, as required.

Chiller condenser bundles shall be equipped with automatic reversing brush-type tube cleaning systems.

Chiller condenser piping shall be equipped with recirculation/bypass valves to maintain incoming condenser water temperature within chiller manufacturer's minimum when outdoor conditions are favorable.

Chiller shall be equipped with base and piping vibration isolation.

Part load efficiency must be considered in the operating features of the design. Specified efficiencies shall be as listed in ARI's application part load value increments to match expected site performance. Refer to ARI Standard 550/590.

Environmental Protection. 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.*

No chlorofluorocarbon (CFC) refrigerants are permitted in new chillers. Acceptable non-CFC refrigerants are listed in EPA regulations implementing Section 612 (Significant New Alternatives Policy (SNAP)) of the Clean Air Act, Title VI: *Stratospheric Ozone Protection*. Note: GSA accepts this criteria in documenting certification of LEED ratings.

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.

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.

Chilled Water and Condenser Water Pumps. Pumps shall be 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 separate pump shall be designed for each condenser water circuit. Variable volume pumping systems should be considered for all secondary piping systems with pump horsepower greater than 10 kW (15 HP). The specified pump motors shall not overload the entire range of the pump curve.

Piping. In general, HVAC systems shall utilize parallel piping systems with a two-pipe main distribution system arranged in a reverse return configuration. If applied, series loop piping for terminal or branch circuits of commercial or institutional systems shall be equipped with automatic flow control valves at terminal units (all types of heat transfer units).

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 branches, such as at each floor level, building wing or mechanical room.

For new chilled water HVAC distribution, a pumping and piping arrangement is generally appropriate, with constant volume primary pumping and variable volume secondary pumping. The primary and secondary circuits shall be separate, with neither having an effect on the pumping head of the other. The primary circuit serves the source equipment (chillers), while the secondary circuit serves the load. Refer also to Pumping Systems in this chapter for additional requirements.

Freeze Protection. Propylene or ethylene glycol manufactured specifically for HVAC Systems is used for freeze protection, primarily in low temperature chilled water systems (less than 4°C) (less than 40°F). The concentration of antifreeze should 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 which have outside 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.

Condenser Water. All water-cooled condensing units must be connected to a recirculating heat-rejecting loop.

Water Treatment. The water treatment for all hydronic 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 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*.

Cooling Towers. Refer to *HVAC, General Parameters, Outdoor Design Criteria* of this chapter for the conditions on which the cooling tower sizes should be based. 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. Cooling towers shall have ladders and platforms for ease of inspections and replacement of components.

Induced draft cooling towers with multiple-speed or variable speed condenser fan controls shall be considered baseline. 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 readily 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 44 m/s (100 MPH) wind design load. Cooling towers shall be constructed of corrosion-resistant materials (stainless steel, fiberglass and PVC) particularly in coastal areas, and for tower components that are typically wet in the normal operation of the tower. If the cooling tower is located on the building structure, vibration and sound isolation must be provided. Cooling towers shall be elevated to maintain a 4-foot minimum clear space beneath the bottom of the lowest structural member, piping or sump, to allow reroofing beneath the tower.

To improve system efficiency, the sequence of operations controlling the cooling tower leaving water temperature should be designed to provide the coldest condenser water that the chillers are designed to handle. Special consideration should be given to deicing cooling towers' fill 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.

Criteria for cooling towers shall also apply to dry fluid coolers.

See Chapter 7: *Fire Protection Engineering*, for fire protection provisions for cooling towers.

Special Cooling Applications

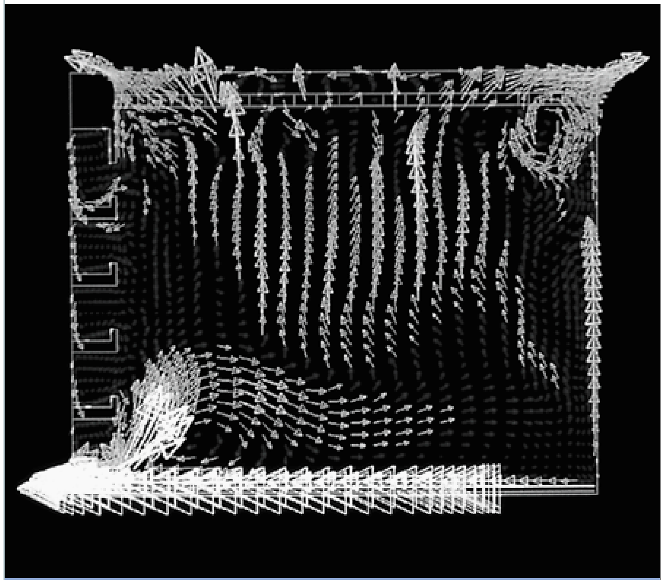
Water-Side Economizer Cycle. In certain climate conditions cooling towers are capable of producing condenser water cold enough to cool the chilled water system without chiller operation. This option shall be considered in life cycle cost comparisons of water cooled chillers. Water-side economizer cycles are particularly cost effective in the low humidity climates of the western United States. In the eastern United States, air-side economizer cycles tend to produce lower operating costs. See section *Air Distribution Systems, Air-Handling Units, Air-Side Economizer Cycle* of this chapter.

Computer Room Air-Conditioning Units. Mainframe computer rooms shall be cooled by self-contained units for loads up to 280 kW (80 tons). These units are 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 280 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 24-hour cooling needs of a computer room should be identified in the *HVAC, HVAC System Components, Sizing and Selection Standards for Equipment and Systems* section of this chapter. 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.

For ventilation, air-handling, and humidification requirements of computer rooms, see section *Air Distribution Systems, Air-Handling Units, Computer Room Air-Handling* of this chapter. The room temperature conditions shown in Table 5-1 provide a higher available temperature for reduced fan power consumption and easier winter humidification. See section *HVAC Design Criteria, Indoor Design Temperatures and Relative Humidity* of this chapter. Verify with users to determine if the air- conditioning system must be connected to emergency power system. These systems should 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.

5.8 Ventilation and Air Distribution



Air Flow Diagram, Atrium, Phoenix Courthouse

Pressurization. Except where natural ventilation is provided as a control strategy, buildings shall be designed to assure a positive pressure with respect to the outdoor environment. The central HVAC systems shall have an active means of measuring and maintaining this positive pressure relationship. The BAS shall alarm when the building pressurization drops below a 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 outside air flow rate required for pressurization. Minimum outside air flow rates shall be adjusted as necessary to assure building pressurization.

Building pressurization shall not be considered to have any effect on envelope heat transfer loads associated with air infiltration.

Special Ventilation Requirements

Toilets. Toilet areas must have segregated exhausts and should be negative in pressure relative to surrounding spaces.

Janitor/Housekeeping Closets. Janitor/Housekeeping closets must have segregated exhausts and should be negative in pressure to surrounding spaces.

Food Service Areas. Kitchen areas shall be negative in pressure relative to adjacent dining rooms, serving areas and corridors. Tempered make-up air shall be introduced at the kitchen hood and/or the area adjacent to the kitchen hood for at least 80 percent of exhaust air. Duct air velocity in the grease hood exhaust shall be no less than 7.5 to 9 m/s (1,500 to 1,800 FPM) to hold particulate in suspension. Dishwashing areas must be under negative pressure relative to the kitchen, and dishwashers shall be provided with their own exhaust hoods and duct systems, constructed of corrosion resistant material.

High Occupancy Areas. High occupancy areas, which also have largely variable occupancies, such as conference rooms, lecture theatres, etc., and are served by dedicated ventilation and air-handling systems, shall incorporate a demand controlled ventilation (DCV) system to minimize energy consumption, while maintaining appropriate levels of ventilation. The DCV system devices shall be located for ease of maintenance and shall provide appropriate operation of the ventilation system it is controlling.

5.9 Air Distribution Systems

Variable Air Volume (VAV) Systems

The baseline air-handling system is a simple VAV system providing cooling only. Any heating requirement (except freeze protection) shall be handled by a separate, dedicated perimeter system. The VAV supply fan shall be designed for the largest block load, not the sum of the individual peaks.

Perimeter Zones. The baseline system utilizes a dedicated hydronic heating system with convectors to offset heat losses through the building envelope in perimeter zones.

Volume Control. Particular attention shall be given to the volume control. VAV systems depend on air volume modulation to maintain the required ventilation rates and temperature set points, which makes terminal air volume control devices critical to the successful operation of the system and shall be provided. 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. Also, the minimum volume setting should equal the larger of the following:

(1) 30 percent of the peak supply volume;
(2) 0.002 m^3/s per m2 (0.4 cfm/ft2) of conditioned zone area; or
(3) minimum m^3/s (cfm) to satisfy ASHRAE Standard 62 ventilation requirements. VAV terminal units must never be shut down to zero when the system is operating. Outside air requirements shall be maintained in accordance with the Multiple Spaces Method, equation 6-1 of ASHRAE Standard 62 at all supply airflow conditions.

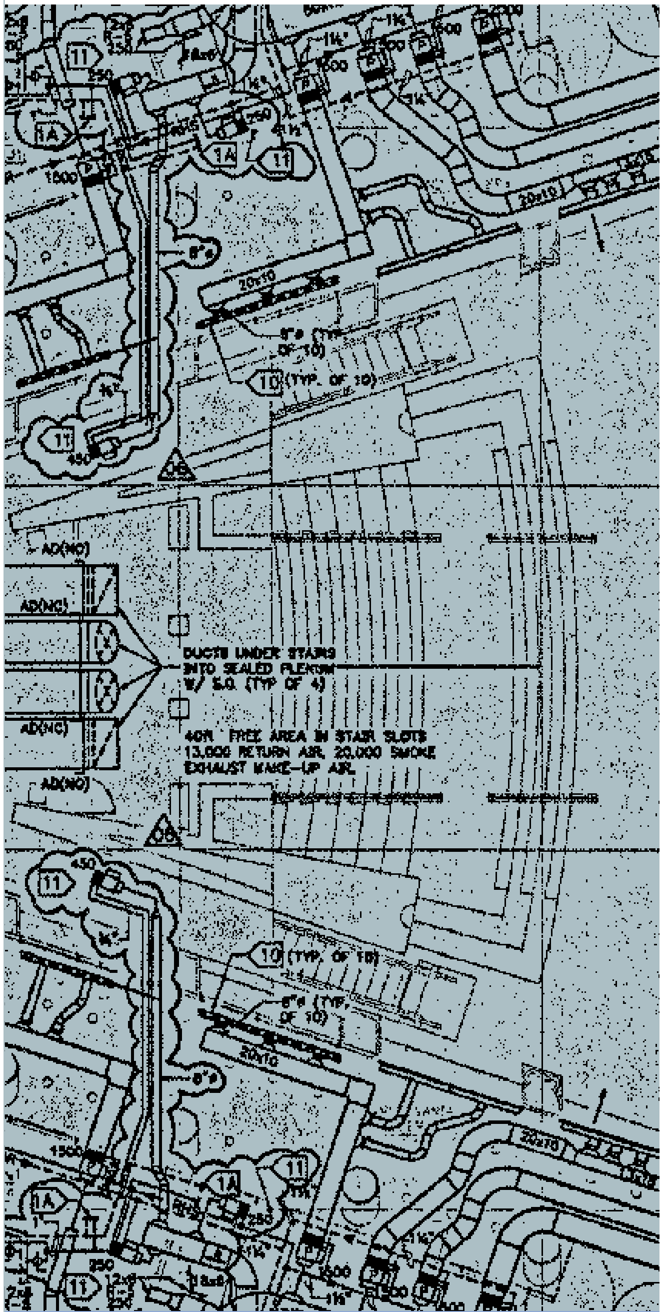
Terminals. VAV terminals shall be pressure-independent type units. Pressure-independent terminal units are more forgiving during the initial start up and testing of the HVAC system and modifications made to the system in the future.

VAV Box Description. 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. Terminals shall be shipped as complete assemblies requiring no field assembly.

All electrical components shall be UL listed and installed in accordance with the requirements of the National Electrical Code.

The terminal casing shall be minimum 22 gauge galvanized steel (20 gauge for fan-powered terminals), internally lined with non-porous, sealed liner which complies with UL 181 and NFPA 255. Insulation shall be 0.7 kg (1.5 lb.) density. Exposed insulation shall be non-fibrous or fiberglass insulation and shall be sealed from the airstream with a foil reinforced liner or solid metal lining.

Damper assemblies shall be heavy gauge steel with shaft rotating in self-lubricating bearings. Nylon bearings are not acceptable. Shafts shall be clearly marked on the end to indicate damper position (removable markings not acceptable). The damper shall incorporate a mechanical stop to prevent overstroking, and a synthetic seal to limit close-off leakage. Actuators shall be externally mounted for service access.



The Federal Triangle Building, Washington, D.C.

For fan-powered terminals the fan shall be constructed of steel and have a forward curved, dynamically balance wheel with direct drive motor. The motor shall be of energy efficient design with integral thermal overload protection and permanently lubricated bearings. Fan assembly shall include an anti-backward rotation device and isolation between motor and fan housing.

Fan-powered terminals shall utilize speed control to allow for continuous fan speed from maximum to minimum, as a means of setting the fan airflow. The speed control shall incorporate a minimum voltage stop to ensure the motor cannot operate in stall mode.

All terminals shall be provided with factory-mounted direct digital controls compatible and suitable for operation with the BAS.

Air Delivery Devices. Terminal ceiling diffusers or booted-plenum slots should be specifically designed for VAV air distribution. Booted plenum slots should not exceed 1.2 meters (4 feet) in length unless more than one source of supply is provided. “Dumping” action at reduced air volume and sound power levels at maximum m^3/s (cfm) delivery should be minimized. For VAV systems, the diffuser spacing selection should 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 should consider the excepted 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, good air mixing, and no objectionable drafts in the occupied space, typically 150 mm (6 inch) to 1830 mm (6 feet) 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.

Noise Control in VAV Systems. System sound levels need to be checked at maximum flow. Inlet guide vanes should be evaluated for noise in their most restricted position. Duct noise control should be achieved by controlling air velocity, by the use of sound attenuators, by the use of acoustically lined ductwork (only on courtroom return air transfer grilles) and by not oversizing terminal units. Terminal units should be selected so that design air volume is approximately three-quarters of the terminal box's maximum capacity. Volume dampers in terminal units should be located at least 1.8 m (6 feet) from the closest diffuser and the use of grille mounted balance dampers should be restricted except for those applications with accessibility problems.

Table 5-3 shows recommended low pressure duct velocities downstream from the VAV terminal unit based on noise generation as the controlling factor.

Table 5-3
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-Handling Units

Air-handling units shall be sized not to exceed 12.1 m^3/s (25,000 cfm) per air-handling unit. Casings and coils of air-handling units shall be sized so that the volume capacity can be increased in the future by 10 percent by replacing the fan. Speed control shall be achieved via variable speed drives.

Filtration. 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. Pre-filters shall be 30 percent to 35 percent efficient. Final filters should be 80 percent to 85 percent efficient for particles at 3 microns. Filter racks shall be designed to minimize the bypass of air around the filter media with a maximum bypass leakage of 0.5 percent.

Filters shall be sized at 2.5 m/s (500 FPM) maximum. Filter media shall be fabricated so that fibrous shedding does not exceed levels prescribed by ASHRAE 52. 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 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.

Humidification. 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 25 percent. Where humidification is necessary, atomized hot water, steam or ultrasound may be used and shall be generated by electronic or steam-to-steam generators. General heating boiler steam shall not be used for humidification. Where summer steam is required for humidification or sterilization, a separate summer steam generator shall be provided and sized for the summer load. Humidifiers shall be centered on the air stream to prevent stratification of the moist air. Where humidification is provided, vapor barriers shall be provided and the surface temperatures of walls and windows must be shown to not be lower than the dew point.

Supply and Return Air Fans. Vane-axial fans are efficient but are more costly than centrifugal fans. Centrifugal double-width double-inlet forward curved and airfoil fans are particularly popular for VAV systems. All fans shall bear the AMCA seal and performance shall be based on tests made in accordance with AMCA Standard 210.

Fans should be selected on the basis of horsepower as well as sound power level ratings at full load and at part load conditions. Since fan sound power level increases as an exponent of static pressure, it is essential that the total system static pressure be kept small.

Fan motors shall be sized so they do not run at overload anywhere on their operation curve. Fan operating characteristics must be checked for the entire range of flow conditions, particularly for forward curved fans. The fan and fan motor shall be internally mounted and isolated on a full-width isolator support frame using isolation springs. The fan discharge shall be connected to the fan using a flexible connection to insure vibration-free operation. Fan drives shall be selected for a 1.5 service factor and fan shafts should be selected to operate below the first critical speed. Thrust arresters should be designed for horizontal discharge fans operating at high static pressure.

Air-Side Economizer Cycle. An air-side economizer cycle reduces cooling costs when outdoor air temperatures are below a preset high temperature limit, usually 15 to 21°C (60°F to 70°F), depending on the humidity of the outside air.

During the life cycle cost analysis, the feasibility of either air- or water-side economizers shall be evaluated for facilities that would otherwise need mechanical refrigeration in cool weather. For water-side economizers see the *Cooling Systems, Special Cooling Applications* section of this chapter.

Enthalpy economizer controls are not recommended because they drift out of calibration easily and may cause energy use to increase. Economizer cycles can be used for humidified spaces, but because of the increased difficulty of maintaining space humidification and control, selection of humidification equipment must be evaluated to minimize operating costs.

If economizer cycles are used in conjunction with heat reclaim chillers, care must be taken in the controls design to avoid having one concept defeat the other. If an economizer cycle is used with the cold deck of a dual duct system, temperature set points may need to be adjusted downward.

Computer Room Air-Handling. In large computer installations (areas of 500 m^2 (5,000 ft^2)) it is recommended to segregate cooling of the sensible load

Table 5-4
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

(computer load) and control of the outside 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 outside 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.

Ductwork

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.*

Energy consumption, security and sound attenuation shall be major considerations in the routing, sizing and material selection for the air distribution ductwork.

Supply and Return Ductwork

Ductwork Pressure. Table 5-4 gives recommended maximum air velocities for ductwork up to 750 Pa (3 inches WG) and minimum velocities for ductwork of pressure ratings above 750 Pa (3 inches WG). 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 should 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 medium pressure classification as a minimum. Secondary air ductwork (runouts/branches from mains to terminal boxes and distribution devices) shall be low pressure classification as a minimum.

Pressure loss in ductwork shall be minimized. 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 m/s (2000 FPM).

Supply and return air ducts shall be designed and constructed to allow no more than 3 percent leakage of total airflow in systems up to 750 Pa (3 inches WG). In systems from 751 Pa (3.1 inches WG) through 2500 Pa (10.0 inches WG) ducts shall be designed and constructed to limit leakage to 0.5 percent of the total air flow.

Sizing of Ductwork. Supply and return ductwork shall be sized using the equal friction method. 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 shall be increased for revisions in future. Air flow diversity shall also be a sizing criterion. Full diversity can be taken at the air-handling unit and decreased the farther the ductwork is from the source until no air flow diversity is taken into account for the final portion of the system.

Ductwork Construction. Generally, ductwork shall be fabricated from galvanized sheet metal. 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. Generally, flex duct runs should not exceed 3 m (10 feet) nor contain more than two bends.

Joint sealing tape for all connections shall be of reinforced fiberglass backed material with field applied mastic. Pressure sensitive tape should not be used as the primary sealant.

Insulation. The insulation shall comply with 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 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.

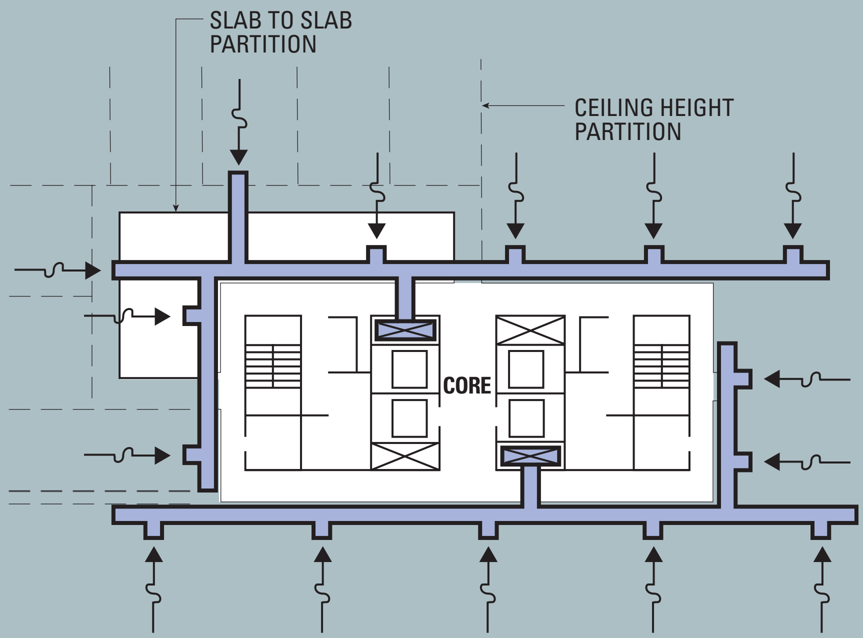
Return air and exhaust air distribution systems shall be insulated in accordance with ASHRAE Standard 90.1. The insulation of return air and exhaust air distribution systems need to be evaluated for each project and for each system to guard against condensation formation and heat gain/loss on a recirculating 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.

Internal duct lining shall only be used on courtroom return air transfer grilles.

Ceiling Plenum Supply. Ceiling plenum supply does not permit adequate control of supply air and shall not be used.

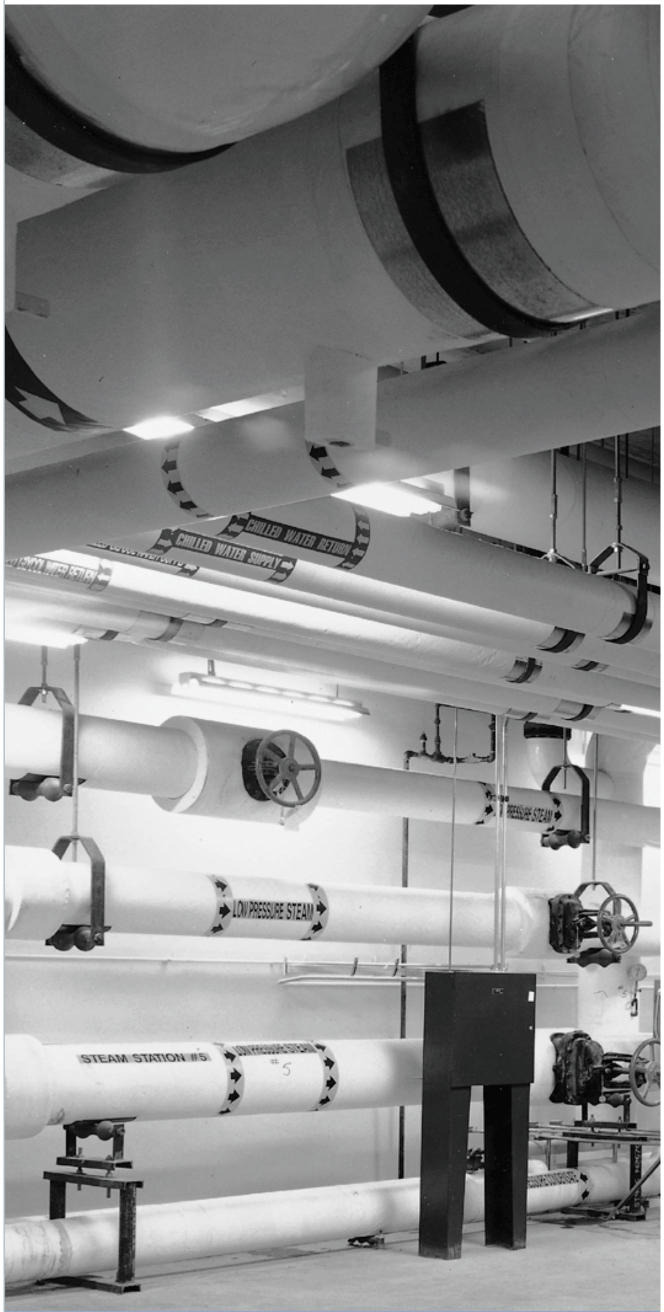
Raised Floor Plenum Supply. In computer rooms, underfoor plenum supplies are appropriate. As a general application in other areas (e.g. open offices), underfloor air distribution systems are appropriate. Where raised floor plenums are used for supply air distribution, the plenums shall be properly sealed to minimize leakage.

Figure 5-2 Ceiling Return Plenum with Minimal Return Ductwork



Plenum and Ducted Returns. 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 46 m (150 feet). No more than 2.3 m^3/s (5,000 cfm) should be collected at any one return grille. Figure 5-2 illustrates an example of an open ceiling plenum with a minimal amount of return air ductwork. All central multi-floor-type return air risers must be ducted.

Other, less flexible building spaces, such as permanent 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.



College Park, Maryland chilled water supply and return

5.10 Plumbing Systems

Water conservation shall be a requirement of all plumbing systems. Water saving plumbing fixtures are essential in this goal.

Domestic Water Supply Systems

Cold Water Service. Cold water service shall consist of a pressurized piping distribution system incorporating a separate supply line from the tap in the existing outside water main to the equipment area inside the building.

Water service shall be metered inside the building by meters furnished by the local department of public works. Remote reading of meters will be accomplished by special equipment over telephone lines. Irrigation systems must be sub-metered for deduct billing of the sewer system.

Internal distribution will consist of a piping system which will supply domestic cold water to all necessary plumbing fixtures, water heaters and all mechanical make-up water needs.

Distribution system shall include equipment that will maintain adequate pressure and flow in all parts of the system in accordance with GSA Facility Standards.

Hot Water Service. Hot water will be generated by heaters utilizing natural gas, electricity or steam as an 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.

Distribution system will consist of a piping system, which connects water heater or heaters to all plumbing fixtures as required. Circulation systems or temperature maintenance systems shall be included. Hot water shall be available at the fixture within 15 seconds of the time of operation.

Domestic Water Supply Equipment. Domestic water supply equipment shall include, but not be limited to the following equipment:

- Water heaters,
- Pressure booster systems,
- Pressure regulating valves,
- Circulating pumps,
- Backflow preventers,
- Balancing valves,
- Isolation valves,
- Hangers and supports, and
- Thermal insulation.

Sanitary Waste and Vent System

Waste Pipe and Fittings. A complete sanitary collection system shall be provided for all plumbing fixtures, floor drains and kitchen equipment designed in compliance with applicable codes and standards.

Piping shall be cast iron soil pipe with hub and spigot joints and fittings. Above ground piping may have no-hub joints and fittings.

Vent Piping and Fittings. System shall be the same as the waste piping above.

Floor Drains. Floor drains shall be provided in multi-toilet fixture restrooms, kitchen areas, mechanical equipment rooms, locations where condensate from equipment collects, and parking garages and ramps. Single fixture toilet rooms do not require floor drains.

In general, floor drains will be cast iron body type with 6 inch diameter nickel-bronze strainers for public toilets, kitchen areas and other public areas. Equipment room areas will require large diameter cast iron strainers and parking garages will require large diameter tractor grates. Drainage for ramps will require either trench drains or roadway inlets when exposed to rainfall. Trap primers shall be provided for all floor drains where drainage is not routinely expected from spillage, cleaning, or rainwater.

Sanitary Waste Equipment. Specific drains in kitchen areas shall discharge into a grease interceptor before connecting into the sanitary sewer. Coordination with the State health department and local authorities will determine which drains.

Floor drains and/or trench drains in garage locations are to discharge into sand/oil interceptors.

Automatic Sewage Ejectors. Sewage ejectors should only be used where gravity drainage is not possible. If they are required, only the lowest floors of the building should be connected to the sewage ejector; fixtures on upper floors should use gravity flow to the public sewer.

Sewage ejectors shall be non-clog, screenless duplex pumps, with each discharge not less than 100 mm (4 inches) in diameter. They shall be connected to the emergency power system.

Thermal Pipe Insulation. 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 condensate 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.

Rainwater Drainage System

Pipe and Fittings. Piping system shall be in compliance with local codes and sized upon local rainfall intensity.

Roof Drains. Roof drains shall be cast iron body type with high dome grates and membrane clamping rings, manufactured by any of the major foundries.

Each roof drain shall have a separate overflow drain located adjacent to it. Overflow drains will be the same drain as the roof drains except that a damming weir extension will be included.

Rainwater Drainage Equipment. Foundations drainage system with perforated drain tile collecting into a sump containing a pumping system as required by the applicable codes shall be provided.

Thermal Pipe Insulation. All piping exposed in plenums or above ceiling shall be insulated to prevent condensation from developing. All insulation materials and accessories shall comply with the fire and smoke hazard ratings indicated by ASTM-E84, NFPA 255 and UL 723.

Plumbing Fixtures

General. Provide all required plumbing fixtures including those that are indicated in the U.S. Courts Design Guides and all penal types. Fixtures shall be as manufactured by reputable companies who have a history of manufacturing. The number, type and style shall be approved by General Service Administration or their representatives.

Natural Gas Systems

Service Entrance. Gas piping entering the building must be protected from accidental damage by vehicles, foundation settlement or vibration. Where practical, the entrance should be above grade and provided with a self-tightening swing joint prior to entering the building.

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 and generators, shall be mechanically ventilated. Vertical shafts carrying gas piping shall be ventilated at top and bottom to prevent leaked gas from accumulating. Gas meters shall be located outside the building, avoiding leakage concerns and providing direct access to the local gas utility.

Diaphragms and regulators in gas piping must be vented to the outside.

Fuel Oil Systems

Fuel Oil Piping. Fuel oil piping system shall use at least Schedule 40 black steel or black iron piping. Fittings shall be of the same grade as the pipe material. Valves shall be bronze, steel or iron and may be screwed, welded, flanged or grooved. Double-wall piping with a leak detection system shall be used for buried fuel piping.

Underground Fuel Oil Tanks. Underground fuel oil storage tanks shall be of double wall, non-metallic construction or contained in lined vaults to prevent environmental contamination. Tanks shall be sized for sufficient capacity to provide 48 hours of heating operation under emergency conditions (72 hours for remote locations such as border stations). For underground tanks and piping a leak detection system, with monitors and alarms for both, is required. The installation must comply with local, State and Federal requirements, as well as EPA 40 CFR 280 and 281.

Fire Protection

Refer to Chapter 7: *Fire Protection Engineering.*

5.11 HVAC Pumping Systems

Hydronic, Closed Loop Systems

Closed piping systems are unaffected by static pressure, therefore, pumping is required only to overcome the dynamic friction losses. 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). This compensates 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.

Variable Flow Pumping. Variable flows occur when two-way control valves are used to modulate heat transfer. The components of a variable volume pumping system include pumps, distribution piping, control valves and terminal units, and will also include boilers and chillers unless a primary-secondary arrangement is used. All components of the system are subject to variable flow rates. It is important to provide a sufficient pressure differential across every circuit to allow design flow capacity at any time.

Flow may be varied by variable speed pumps or staged multiple pumps. Pumps should operate at no less than 75 percent efficiency for their performance curve. Variable flow pumping must be designed carefully. Package systems should be used, with pumps and controls supplied in the complete package having received factory testing prior to shipment.

Chillers and most boilers may experience flow-related heat exchange problems if flow is not maintained above a minimum rate. For this reason, separate, constant flow primary water pumps are recommended for variable volume pumping systems.

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.

Primary/secondary pumping arrangements allow increased system temperature design drops, decreased pumping horsepower and increased system control. 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 76 L/s (1,000 gpm)) and campus facilities.

5.12 Piping Systems

All piping systems should 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.)

Cathodic Protection. The need for metal protection for underground piping must be evaluated by a soils resistivity test. This is part of the Geotechnical Report. See Appendix A. Cathodic protection or another means of preventing pipe corrosion must be provided.

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

Isolation of Piping at Equipment. Isolation valves, shut-off valves, by-pass circuits and unions shall be provided as necessary 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.

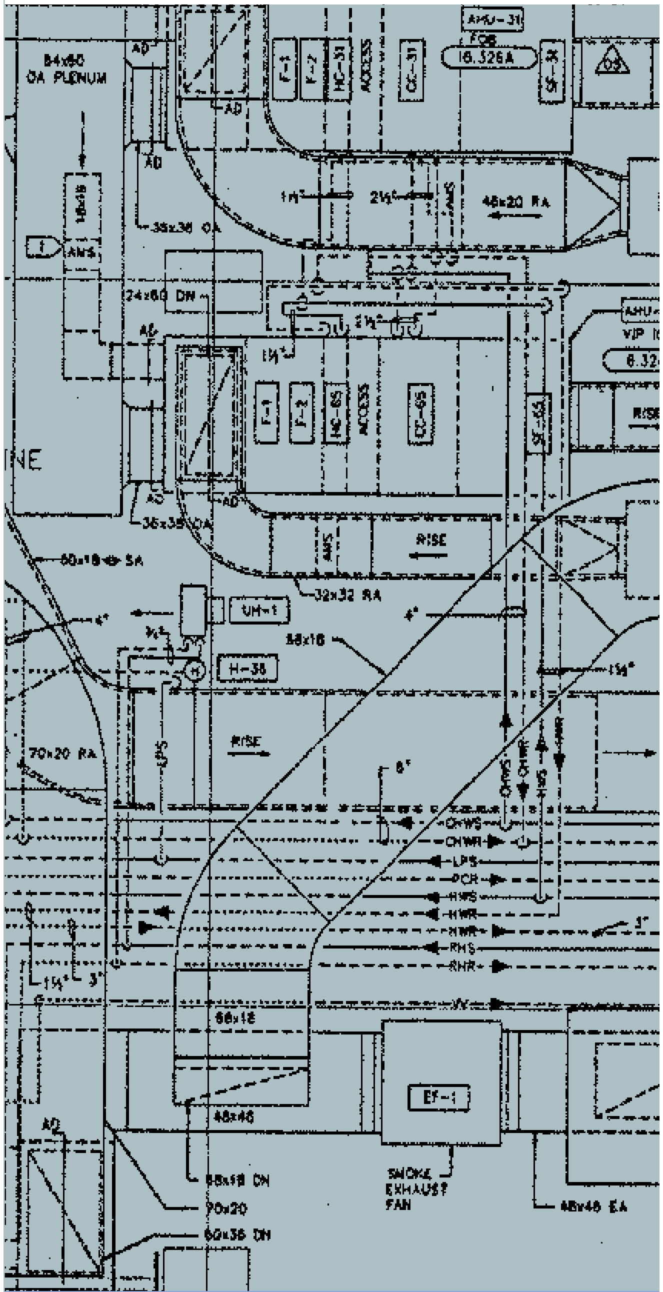
Provisions for Piping in Earthquake Zones. In Seismic Zones 2, 3 and 4, sleeves for pipes shall be at least 25 mm (1 inch) larger than the pipe, to allow for movement. Flexible couplings shall be provided at the bottom of pipe risers. Spreaders shall be used to separate adjacent pipes, unless the distance 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 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 type the system and direction of flow for piping systems or type and number for equipment. The identification system shall also tag all valves and other operable fittings. Gas piping and sprinkler lines must be identified as prescribed by NFPA.

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, those having design temperatures less than 18°C (65°F) or greater than 40°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 to whether piping is concealed or exposed. Chilled water piping systems shall be insulated with non-permeable insulation (of perm rating 0.00) such as cellular glass.

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.	035 kPa (150 psi) fittings. Standard weight pipe over 300 mm (12-in) diameter.
	Hot water	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	



Mechanical room part plan, The Federal Triangle Building, Washington, D.C.

5.13 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 ASHRAE *Applications Handbook, Sound and Vibration Control.*

Isolate all moving equipment in the building.

Mechanical Room Isolation. Floating isolation floors should be considered for major mechanical rooms located in penthouses or at intermediate levels in mid-rise and high-rise construction. See Chapter 3: *Architectural and Interior Design, Special Design Considerations, Acoustics, Design Criteria for Building Spaces, Class X Spaces.*

Mechanical Chases. Mechanical chases should be closed at top and bottom, as well as the entrance to the mechanical room. Any piping and ductwork should 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, except that shafts dedicated to gas piping must be ventilated.

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

Concrete Inertia Bases. Inertia bases should be provided for reciprocating and centrifugal chillers, air compressors, all pumps, axial fans above 300 RPM, and centrifugal fans above 37 kW (50 HP).

Ductwork. Reduce fan vibrations immediately outside 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.

Piping Hangers and Isolation. Isolation hangers should be used for all piping in mechanical rooms and adjacent spaces, up to a 15 m (50-foot) distance from vibrating equipment. The pipe hangers closest to the equipment should have the same deflection characteristics as the equipment isolators. Other hangers should be spring hangers with 20 mm (.75 inch) deflection.

Positioning hangers should be specified for all piping 200 mm (8 inches) and larger throughout the building. Spring and rubber isolators are recommended for piping 50 mm (2 inches) 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 should 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 should be designed into the piping before it reaches the riser.

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

5.14 HVAC Control Systems

Automatic Temperature and Humidity Controls

A Direct Digital Control (DDC) system with host computer controlled monitoring and control shall be provided.

Controls. Pre-programmed stand-alone single or multiple loop controllers shall be used to control all HVAC and plumbing sub-systems.

Temperature Controls. 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 façade of the building with a different orientation.

The sequences controlling the heating and cooling to spaces shall minimize the magnitude to which they are provided simultaneously. A 2.5°C (5°F) deadband 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.

Temperature Reset Controls

Air Systems. Systems supplying heated or cooled air to multiple zones must include controls that automatically reset supply air temperature by representative building loads or by outside 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 by representative temperature changes responding to changes in building loads (including return water temperature) or by outside air temperature.

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 Damper Position (economizer) Supply Air Discharge Temp Return Air Temp Mixed Air Temp Supply Air Flow Rate Outside Air Flow Rate Return Air Flow Rate	**Refrigeration Equipment** Start/Stop Leave Water Temp Reset Demand Limiting Isolation Valve Position Leaving Water Temp Entering Water Temp kW Draw Flow	**Hot Water Boilers** Start/Stop Leaving Water Temp Reset Isolation Valve Position Leaving Water Temp Entering Water Temp Flow
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	**Pumps** Start/Stop Discharge Pressure Reset
Utilities Natural Gas – Consumption Electricity – Consumption & Demand Water – Consumption Fuel Oil – Quantity		

5.15 Building Automation Systems (BAS)

The primary reason for using a BAS is the anticipated lower operating cost over the life of the building. Programmable controllers monitor and 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 monitor systems such as HVAC, lighting, elevators, security controls and fire alarms. The BAS can be programmed to cycle and schedule equipment for preventive maintenance and maintain parts inventories. For optimal function, the BAS should be integrated with the basic building HVAC controls system.

A BAS is not required for every project and should be a part of the life cycle cost analysis. The size of the building, number of pieces of equipment, expected energy savings and availability of trained staff should all be considered before a decision is made. BAS' are mandatory and considered part of the baseline system on large facilities (above 9,300 gross square meters (100,000 gross square feet)), both new facilities and major modernizations.

Level of Integration. It is possible to combine controls for practically all building systems—HVAC, lighting, emergency power, and elevators—into a single-CPU operating unit. Since the advent of micro-computer BAS systems, there has been an attempt to integrate as many systems as possible to reduce hardware requirements. However, caution is advised when planning BAS systems with a high level of integration. The more integration, the more complex the system becomes and the more training is required for the operating staff. Also, reliability requirements for the different systems may vary.

Fire alarm systems, security systems and elevator systems shall not be integrated, that is controlled by a BAS. These systems should 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 Engineering, Electrical Requirements, Fire Alarm Systems*, and Chapter 8: *Security Design*.

BAS' shall utilize 'open' communication protocols, such as BACnet, ASHRAE Standard 135 – 1995, 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.

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.

Energy Conservation. The best targets for energy conservation in building systems are the HVAC system and the lighting system. 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 comfort set points.

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.

A number of programs are available to control building lighting. They include timers and sweeps for on/off control and photocell controlled switching for taking full advantage of daylight.

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 set points 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. Stand-alone control panels and terminal unit controllers can have text-based user interface panels which are hand-held or fixed.

Energy Measurement Instrumentation. The capability to allow building staff to measure energy consumption and monitor performance is critical to the overall success of the system. Electrical values, such as V, A, kW, KVAR, KVA, PF, kWh, KVAH, Frequency and Percent THD, shall be measured. See also Chapter 6: *Electrical Engineering, Site Distribution*, for separate metering of power consumption.

Ronald Reagan Building, Washington, D.C.

5.16 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 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 outside 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 outside 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.

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.

Water Use Meters. See *Plumbing Systems, Domestic Water Supply Systems.*

Indoor Air Quality Measurement. Vehicle garage exhaust fans shall generally be activated based upon carbon monoxide sensors within the garage. Carbon monoxide sensors shall also be located in upper floor areas where vertical shafts penetrate to vehicle garage areas.

5.17 Start-up, Testing, and Balancing Equipment and Systems

Start-Up. The A/E shall specify that factory representatives be present for startup of all major equipment, such as boilers, chillers 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 either Associated Air Balance Council (AABC) or National Environmental Balance Bureau (NEBB).


National Building Museum, Washington, D.C.

5.18 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 at 20 years life or older 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 should 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 at three basic scales: refurbishment of an area within a building, such as a floor or a suite; major renovation of an entire structure; and upgrade/restoration of historic structures.

In the first instance, the aim should 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 should be attempted.

In the second case, 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.

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

Modern standards for climate control developed for new construction may not be achievable or desirable for historic buildings. In each case, the lowest level of intervention needed to successfully accomplish the project should be selected. 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 should be followed for HVAC work in historic buildings:

- 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.
  - — Add insulation where not visible and intrusive, such as attics or basements. Insulate walls only where it can be done without removal or covering original visible elements.
  - — Add storm windows where they can be installed in a manner that will not detract from original visible elements.
  - — Use new replicated thermal windows only where it is not economically feasible to repair existing windows.
- 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. Consider reuse of existing components when reuse will reduce architectural intrusion and achieve savings, without compromising overall performance and life cycle requirements. 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.
- Use a number of smaller units in lieu of a few large ones. Insure that room is available to maintain and replace equipment without damaging significant features to the greatest extent possible, selecting components that can be installed without dismantling window or door openings.
- Place new distribution systems out of sight whenever possible by using closets, shafts, attics and basements.
- Use custom rather than commercial standard products where elements are exposed in formal areas.
- Select temperature and humidity conditions that will not accelerate deterioration of building materials.

- Where equipment is near significant features, insure that leakage from pipes and HVAC units will not cause deterioration. Use deeper condensate drain pans, lined chases and leak detectors.

- Design HVAC systems to avoid impacting other systems and historic finishes, elements and spaces.

- Place exterior equipment where it is not visible. Be particularly careful with new chimneys or vents and condensers, towers, solar panels and air intakes and discharges. Recess equipment from the edge of the roof to minimize visibility of the equipment from grade. Alternatively, explore creating 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 façade.
  - — Locate equipment with particular care for weight and vibration on older building materials. These materials may not accept the same stress as when the equipment is used with newer construction methods.
  - — 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 outside. This is the area of highest natural illumination, and it can be used to reduce the need for artificial illumination, which will in turn reduce the size of HVAC systems. Original plaster ceilings in significant spaces such as lobbies and corridors should 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.
  - — Locate pipes so that they do not damage or visually interfere with character-defining elements in historic structures such as windows, doors, columns, beams, arches, baseboards, wainscots, paneling, cornices, ornamental trim, decorative woodwork and other decorative treatments of floors, walls and ceilings.
  - — **Vertical Distribution.** If new risers are required, they should preferably be located adjacent to existing shafts.
  - — **Horizontal Distribution.** Many older buildings have high floor-to-floor heights, which permit an option to use an existing ceiling space.

- In buildings containing ornamental or inaccessible ceilings, piping and ductwork may 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 should also be considered in historic industrial buildings and open plan, tall ceiling, high window spaces suited to flexible grid/flexible density treatments.