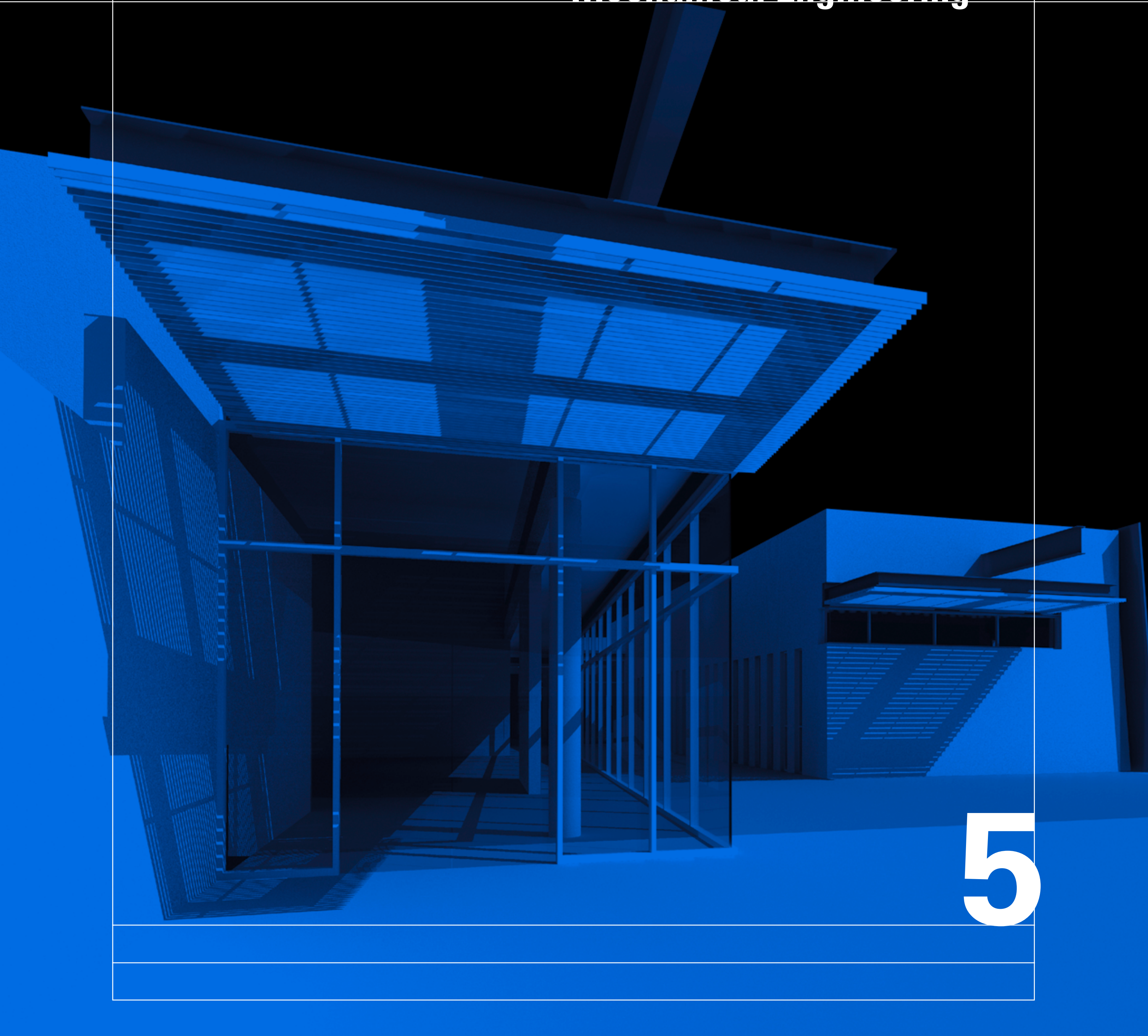
Mechanical Engineering



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Temecula Border Patrol Station, Murietta, California
Architect: Garrison Architects
GSA Project Manager: Steve Baker

5.1 General Requirements

This chapter identifies criteria to program and design heating, ventilating and air conditioning (HVAC) and plumbing systems.

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

Mechanical systems shall be specifically designed to function at full load and part load associated with all projected occupancies and modes of operation. To the maximum extent possible, system solutions 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 retrofitting Courtroom facilities for other Agencies' use. See Chapter 9, "*Design Standards for U. S. Court Facilities,*" for design criteria.)

The design of the mechanical systems shall generally be more demanding in performance expectations than represented within *ASHRAE 90.1* and *10 CFR 434* standards. All mechanical systems shall be designed to automatically respond to the local climatic conditions and heat recovery opportunities to provide cost effective energy conservation measures while assuring set point control. The design of mechanical systems and other building components shall all combine together to produce a building that meets the project's programmed sustainability rating (LEED rating) and assigned energy target, as referenced in Chapter 1.

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

Standby capacity shall be designed into mechanical systems, enabling continuous services during repair or replacement of a failed piece of equipment or component. Redundant equipment shall typically 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 by GSA for their offerings of advanced technology; however, GSA does not allow use of experimental, unproven, or proprietary equipment or systems. Documented proof of historical capability and adaptability of all equipment and systems proposed for a project shall be made available to GSA.

As indicated herein, the description of the mechanical baseline systems establishes the minimum level of quality, function, and performance that may be considered.

Submission requirements are addressed in Appendix A.3.

5.2 Codes

Mechanical Codes

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

5.3 Standards

Mechanical Design Standards

The latest editions of publications and standards listed here are intended as guidelines for design. They are mandatory only where referenced as such in the text of this chapter or in applicable codes. The list is not meant to restrict the use of additional guides or standards. When publications and standards are referenced as mandatory, any recommended practices or features shall be considered "required." When discrepancies between requirements are encountered, GSA shall determine the requirement.

- *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 Standard for Buildings Except Low-Rise Residential Buildings.*
- *ASHRAE: Standard 100: Energy Conservation in Existing Buildings.*
- *ASHRAE: Standard 105: Standard Method of Measuring and Expressing Building Energy Performance.*
- *ASHRAE: Standard 111: Practices for Measurement, Testing, Adjusting and Balancing of Building HVAC Systems.*

- *ASHRAE: Standard 114: Energy Management Control Systems Instrumentation.*
- *ASHRAE: Standard 135: BACnet: A Data Communication Protocol for Building Automation and Control Networks.*
- *ASHRAE: Guideline #4: Preparation of Operating and Maintenance Documentation for Building Systems.*
- 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):
- *ASHRAE HVAC System Duct Design.*
- *SMACNA HVAC Duct Construction Standards: Metal and Flexible.*
- *SMACNA HVAC Air Duct Leakage Test Manual.*
- *SMACNA Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems.*
- *Seismic Restraint Manual Guidelines for Mechanical Systems.*
- NFPA Standard 96
- All applicable regulations and requirements of local utility companies having jurisdiction.
- EIA/TIA Standard 569: *Commercial Building Standard For Telecommunications Pathways And Spaces* (and related bulletins).

5.4 Program Goals

Design Integration

As represented in Appendix A-2, mechanical systems must be selected to routinely address multiple program goals, including: workplace performance, sustainability, energy efficiency, security, fire safety, historic preservation and operations/maintenance concerns, as well as other project expectations. Design solutions shall not sacrifice the basic needs of one program area to optimize another. Instead, mechanical designs must optimize program areas to the extent possible, assuring attainment of all critical performance goals. Prior to making any mechanical systems solutions, their designer shall visit the Whole Building Design Guide website, **www.wbdg.org,** to identify program goal principles and to consider available technologies.

Life Cycle Costing

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

The baseline HVAC systems described in the following section set minimum system requirements and act as a reference from which advantages and disadvantages of other systems or sub-systems can be compared.

Any deviation from the GSA defined baseline standards or from the directives described herein shall not be permitted unless previously identified in project programming requirements, and submitted directly to and subsequently authorized by the Office of the Chief Architect.

5.5 HVAC Baseline Systems

Baseline Selection

Unless otherwise directed in design programming documents, a combination of the following perimeter and interior HVAC systems shall be used to set a base reference for comparison.

Perimeter Systems. Perimeter zones shall have 100-percent outside air dedicated ventilation systems sized to meet the ventilation requirements of the specified zone. These systems shall provide tempered dehumidified air and shall be completely independent of any other air distribution system. In addition to the dedicated 100-percent outside air ventilation system(s), the perimeter zones shall also have a baseline perimeter heating and cooling system selected from the following:

- For new construction spaces with significant latent loads and/or for alterations to existing space with ceiling distribution, use a ducted overhead variable air volume (VAV) air distribution system with VAV shutoff boxes for cooling and hot water fin-tube systems for heating.
- A ducted overhead variable air volume (VAV) air distribution system with fan-powered VAV boxes with hot water heating coils for cooling and heating.[1]
- For new construction office type loads and other spaces with low latent loads, use an underfloor, variable air volume (VAV) air distribution system, for cooling, supplemented with two-pipe, above floor perimeter hot water fin-tube systems for heating.
- For alteration projects with high skin loads use a standard four-pipe fan coil unit system for heating and cooling.

Interior Systems. Interior zone(s) shall have 100 percent outside air ventilation system(s) to meet the ventilation requirements of the interior zone. The ventilation system(s) shall operate independently of any other air distribution system but shall connect to the return side of the VAV air-handling unit(s) serving the interior zone(s). The interior zone(s) shall also have a baseline interior heating and cooling system selected from the following:

- A ducted overhead variable air volume (VAV) system with VAV boxes.
- A ducted overhead variable air volume (VAV) system with fan-powered VAV boxes.[2]
- An underfloor variable air volume (VAV) air distribution system.

[1] Electric heating coils will be permitted for nominal heating requirements. Requests for use of electric heating coils must be submitted directly to and subsequently authorized by the office of the Chief Architect. No reheat is permitted.

[2] Hot water heating coils in the fan-powered VAV boxes may be used on the top floor of a building for heating.

General

- Enthalpy heat recovery shall be used for interior zones and other special areas where the outside air exceeds 30 percent of the total supply air quantity.
- Special areas such as auditoriums, atriums, and cafeterias shall have a dedicated air-handling unit with individual controls to condition these spaces as required.
- A dedicated air-handling unit shall be provided for maintaining positive pressure in the main entry lobby.
- Air-handling units with a capacity over 1,416 LPS (3,000 CFM) shall have an enthalpy economizer cycle. Systems dedicated to serving only unoccupied spaces with intermittent operation, such as elevator machine rooms, telephone equipment rooms and similar spaces would be exempt from the requirements of having an economizer cycle.
- Waterside economizer system shall be employed where airside enthalpy economizer is not practical or feasible. Systems dedicated to serving only unoccupied spaces with intermittent operation, such as elevator machine rooms, telephone equipment rooms and similar spaces would be exempt from the requirements of having an economizer cycle.

5.6 Design Criteria

General Parameters

HVAC system parameters are provided here for reference, but specific energy performance directives are also listed in 10 CFR 434. 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 for sensible heat load calculations shall be based on the 0.4 percent dry bulb temperature with its mean coincident wet bulb temperature. Design conditions for the summer ventilation load and all dehumidification load calculations shall be based on the 0.4% dew point with its mean coincident dry bulb temperature.

Indoor Design Criteria

Indoor Design Temperatures and Relative Humidity. Indoor design temperatures and relative humidity requirements are stated in Table 5-1. 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. Air can be returned from the dining area space. The air from these spaces must be exhausted directly to the outdoors.

Building Pressurization. To keep dry air flowing through building cavities, systems shall be designed with sequence of operations that assure continuous positive pressure with respect to the outdoor environment until the outdoor temperature falls below 4.5°C (40°F), when the building pressure shall be brought to neutral. These building 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 predetermined low limit. In areas where exhaust systems are used or an indoor air quality contaminant source is located, a negative pressure shall be maintained relative to surrounding spaces. Calculations shall be provided that show the minimum outside airflow rate required for pressurization. Minimum outside airflow rates shall be adjusted as necessary to assure building pressurization.

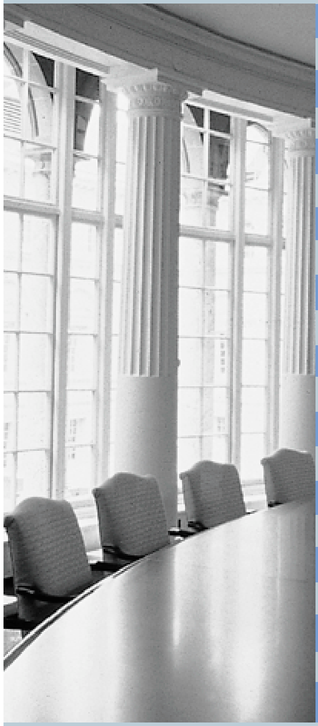
Artwork. In general, it is important to keep within an RH range of 30 to 70%. In a hot and dry geographic region it makes sense to maintain a range that errs on the low side (20 to 40%), while in semitropical climates a range of 55 to 75% may be practical.

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

Energy Analysis. An energy analysis of building characteristics, the mechanical and electrical components, and all other related energy consumption elements must be performed for each design submission level project as described in Appendix A.3.

Analyses of energy-conserving designs shall include all relevant facets 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 building automation equipment to automatically adjust for building partial occupancies, optimized start-stop times and systems resets. Energy analysis shall utilize public domain DOE-2 programs. Inputs and outputs shall follow *ASHRAE 90.1 Standards* and *10 CFR 434*.

Table 5-1
Indoor Design Conditions[3]



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

*Requires humidification in the winter.

Notes:

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

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
Kitchen supply and exhaust air	7	25

* Roof intakes must be at least 0.2 m (8 inches) above the average maximum snow depth and the potential for drifts at the intake location must be considered. Outdoor intakes should be covered by 13 mm (0.5 inch) mesh screen. The screen should be of corrosion-resistant material and located outside of or no more that 0.2 m (8 inches) inside of the outside face of the intake grille, louver, or rain hood entry. On buildings of more than four stories the outside air supply louvers shall be located on the fourth level of the building or higher. On buildings of three stories or less, locate the intakes on the roof or as high as possible. Locating intakes high on the exterior wall is preferred to a roof location. Outside air intake is not permitted within seven meters (twenty-five feet) of loading dock or any other fume producing areas.

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

Indoor Air Quality. When a building is new, volatile compounds (VOC) may be released in large quantities from materials, such as adhesives, vinyl and carpets. An outside air purge cycle shall be provided to air-handling equipment enabling evening removal of VOC build-ups 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 percent 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 airborne sources of contaminants that may be unacceptable for use indoors with respect to odor and sensory irritation.

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 usable square meters (100 usable square feet). Within areas occupied by workstations, the occupancy load can be as dense as one person per 7 usable square meters (75 usable 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, auditoriums and other high occupancy spaces, occupancy loads should represent the number of seats available. Areas 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 estimated receptacle demand load outlined in Chapter 6, "*Electrical Engineering, Electrical Load Analysis,*" and anticipated needs of GSA's Office of Chief Information Officer. For printers and personal computers, 80 percent diversity shall be considered.

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.

Zoning Criteria

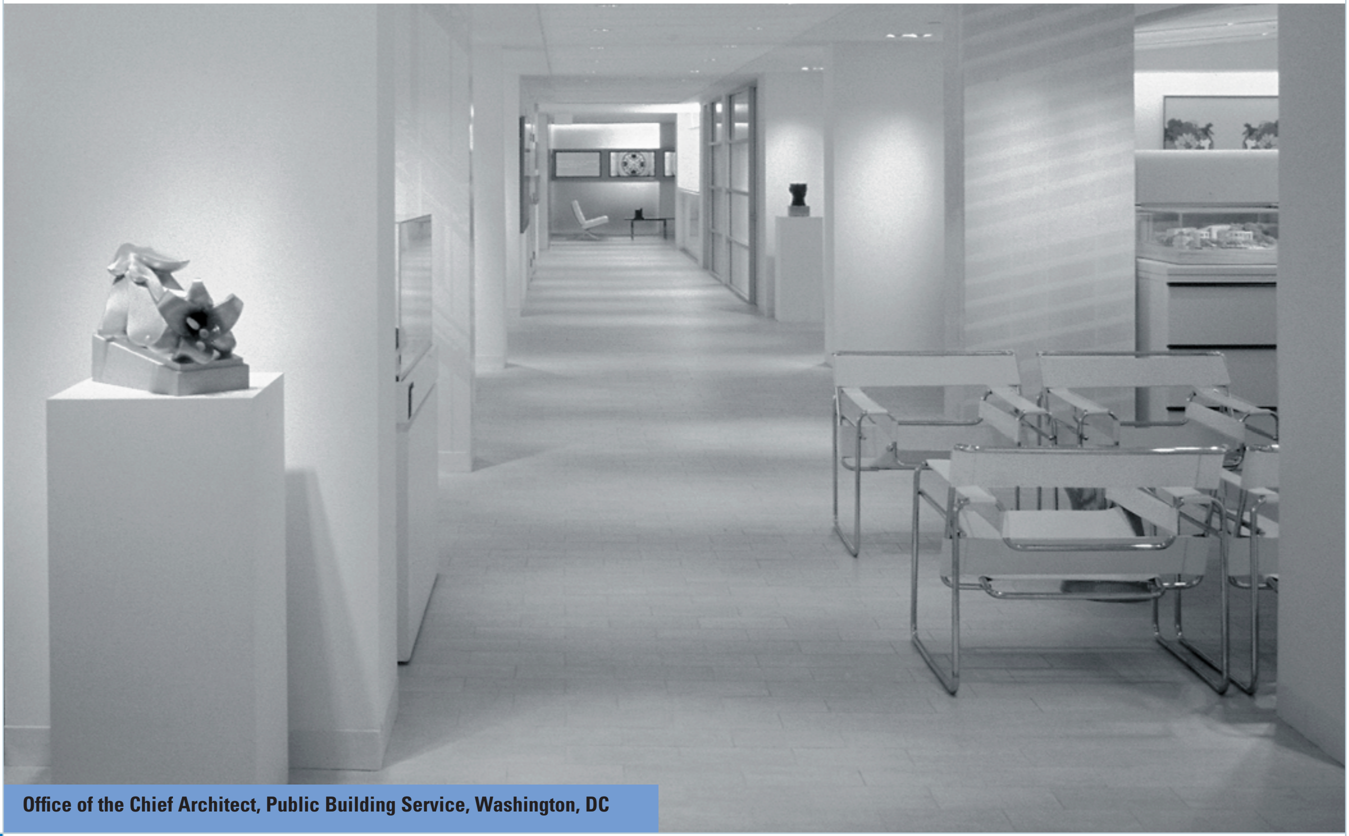
Separate systems shall be provided for interior and perimeter zones where simultaneous heating and cooling operations may occur.

Single air handling units shall not serve multiple floors or scattered building loads. Multiple air handling units or floor-by-floor systems shall be considered as baseline. Systems designed for federal courthouses shall be limited to having no more than two courtrooms served by any single air handling unit, and that air handling unit shall be dedicated to serving only those two courtrooms.

Interior control zones must not exceed 180 m^2 (1,500 sf) 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, atriums, kitchen areas, dining areas, childcare centers and physical fitness areas. Perimeter zones shall not exceed 30m^2 (300 sf).

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.

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.



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

5.7 Arrangement of Mechanical Spaces

Minimum Space Requirements. A minimum of 4 percent of the typical floor's gross floor area shall be provided on each floor for air-handling equipment. A minimum of 1 percent of the building's gross area shall be provided for the central heating and cooling plant (location to be agreed upon during preparation of concept submission. Space requirements of mechanical and electrical equipment rooms shall be based upon the layout of required equipment drawn to scale within each room.

Service Access. Space shall be provided around all HVAC system equipment as recommended by the manufacturer and in compliance with local code requirements for routine maintenance. Access doors or panels should be provided in ventilation equipment, ductwork and plenums as required for in-site 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. The HVAC design engineer should be cognizant of the necessity to provide for the replacement of major equipment over the life of the building and should insure that provisions are made to remove and replace, without damage to the structure, the largest and heaviest component that cannot be further broken down.

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

Vertical Clearances. Main 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 [45 kg (100 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).

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

Housekeeping Pads. Housekeeping pads shall be at least 150 mm (6 inches) wider on all sides than the equipment they support and shall be 150 mm (6 inches) thick.

Mechanical equipment rooms must be designed in accordance with the requirements of *ASHRAE Standard 15: Safety Code for Mechanical Refrigeration.*

5.8 Mechanical Requirements for Special Spaces

United States Courthouse, White Plains, NY

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

Auditoriums. Auditoriums shall have dedicated air-handling units equipped with enthalpy economizer cycle. Units shall be designed with 80 percent diversity factor to maintain necessary temperature and humidity conditions under partial loads and partial occupancy. Provide dewpoint control. Dewpoint of supply air shall not exceed 10°C (50°F) dry bulb.

U.S. Marshals Service Areas. The U.S. Marshals Service area HVAC system shall be designed for continuous operation and shall be independently controlled and zoned. All ductwork and air circulation openings penetrating the secure area envelope, including prisoner circulation areas, shall be provided with security bars. Detainee holding areas shall be negatively pressurized with regard to adjacent spaces and exhausted directly to the outdoors. Refer also to requirements of 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 occupant comfort conditions and to maintain a positive pressure in this area relative to down range and target area. Powered exhaust air shall be extracted from down range and the target areas in sufficient quantity to remove smoke and maintain a clear line of vision to the target. Sixty percent of the total exhaust shall be extracted at a point approximately one-third the distance from the firing line to the target area, and forty percent shall be extracted from above the target area. All exhaust air shall be filtered to preclude the emission of lead particulates and gunpowder residue into the atmosphere. Discharge of firing range exhaust air to outdoors shall be carefully located to prevent recirculation into the outside air intake of any HVAC system. Firing range systems shall be capable of continuous operation, isolated from other building systems.

Kitchens and Dishwashing Areas. Kitchens with cooking ranges, steam kettles, ovens and dishwashers shall be provided with dedicated make-up air and exhaust hoods/exhaust systems in accordance with 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 affect the pressure relation between the kitchen and surrounding spaces. Both supply air and makeup air shall be exhausted through the kitchen hood heat recovery system while a maximum of 30 percent of the exhaust air is made up from the space.

Floor drains must be provided at each item of kitchen equipment 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.

Areas of Refuge. The area of refuge provided for the Judiciary in the event of emergency conditions shall be provided with adequate ventilation energized from the emergency power distribution system and sufficient heating capacity to maintain space temperature of 21°C (70°F) with design winter outdoor temperature. Provide separate air-handling unit to maintain positive pressure, relative to surrounding spaces, with heating-cooling coils and differential pressure sensing system.

Mechanical Rooms. All mechanical rooms must be mechanically ventilated to maintain room space conditions as indicated in *ASHRAE 62, ASHRAE 15,* and Table 5-1 of this chapter. Water lines shall not be located above motor control centers or disconnect switches and shall comply with requirements of *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.

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

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

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

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

Emergency Generator Rooms. The environmental systems shall meet the requirements of NFPA Standard 110: *Emergency and Standby Power Systems* and meet the combustion air requirements of the equipment. Rooms must be ventilated sufficiently to remove heat gain from equipment operation. The 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 should be avoided.

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 distribution system. 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. Acoustical enclosures shall be provided to maintain a maximum NC level of 35. Coordinate with electrical design specifications to include HVAC support equipment in UPS extended servicing agreements.

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

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

Artwork. In general, it is important to keep within an RH range of 30 to 70%. In a hot and dry geographic region it makes sense to maintain a range that errs on the low side (20 to 40%), while in semitropical climates a range of 55 to 75% may be practical.

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

Fire Protection and Smoke Control. Refer to Chapter 7: *Fire Protection Engineering,* for fire protection and smoke control requirements.

5.9 HVAC Systems and Components

HVAC Systems

Perimeter Outside Air Ventilation Systems. Perimeter ventilation units shall be self-contained DX package units or air-handling units with fan section having variable speed drive, chilled water cooling coil, hot water heating coil, enthalpy heat recovery wheel, or desiccant wheel and supply air filtration. The perimeter ventilation units shall provide 100-percent outside air. Reheat shall be hot gas bypass, a heat pipe or a run around coil. Chilled water shall be generated by an air-cooled chiller or a 24-hour chiller. If a desiccant wheel is used for controlling the specific humidity discharge at the wheel, condenser reheat shall be used for regeneration of the desiccant, along with minimum electric backup. Supply air dew point leaving the unit shall be maintained at 10°C (50°F) and the supply air dry bulb temperature leaving the air-handling unit shall be a minimum of 21.1°C (70° F) and not greater than 25.6°C (78° F) during occupied hours. During occupied hours, this unit shall operate to deliver conditioned ventilation air and maintain positive pressure in the perimeter zone with respect to outside air pressure. During unoccupied hours, the unit shall run at 40 percent of its capacity to provide conditioned air at 10°C (50° F) dew point and at least 21.1°C (70°F) to help maintain positive pressure in the perimeter zone with respect to outside air. In both the occupied and unoccupied modes the system shall operate to adjust the airflow as required to maintain a differential positive pressure in the perimeter zone relative to the prevailing pressure outside the building. When the outside air dew point drops below 2.8°C (37°F), the unit shall have the capacity to maintain neutral pressure with respect to the outside by exhausting relief air from the return duct system. The ventilation unit shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS direct digital control (DDC) Building Automation System. It shall also be equipped with dampers to set the design airflow through the unit, and also an analog or digital display which measures and displays the amount of air flowing through the unit continuously.

Interior Outside Air Ventilation Systems. Interior ventilation units shall be self-contained DX packaged units or air-handling units with chilled water-cooling coil, hot water heating coil, and supply air filtration. Interior ventilation units shall incorporate enthalpy heat recovery wheel or desiccant wheel, heating coil, and a cooling coil. Heat recovery shall include use of building relief and exhaust air. Utilize condenser waste heat for desiccant regeneration. The supply air from the ventilation units shall be ducted to the return plenum section of the air-handling unit(s) serving the interior zones. Supply air dew point leaving the unit shall be maintained at 10°C (50°F) and the supply air dry bulb temperature shall be a minimum of 21.1°C (70° F) and not greater than 25.6°C (78° F). During occupied hours, this unit shall operate to provide conditioned ventilation air. The unit shall be inoperative during unoccupied hours. The unit shall have air-monitoring devices to indicate that the supply air is always 10 percent greater than the exhaust/relief air. The dedicated ventilation unit shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS Direct Digital Control (DDC) Building Automation System. It shall also be equipped with dampers to set the design airflow through the unit, and also an analog or digital display which measures and displays the amount of air flowing through the unit continuously.

Fan Coil System. For perimeter spaces, provide four-pipe fan coil units with cooling coil, heating coil, 35 percent efficiency filters, internal condensate drain, and overflow drain. Unit shall have self-contained microprocessor controls and shall be capable of connecting to and interoperating with a BACnet or LONWORKS Direct Digital Control (DDC) Building Automation System. Fan coil units shall be capable of operating with unit mounted or remote mounted temperature sensor.

Fin Tube Heating Systems. When fin-tube radiation is used, reheat should not be featured with perimeter air distribution systems. Fin-tube radiation shall have individual zone thermostatic control capable of connecting to a self-contained microprocessor that can interface with a BACnet or LONWORKS Direct Digital Control (DCC) Building Automation System.

Variable Volume System with Shutoff Boxes. Variable Air Volume (VAV) systems with full shutoff VAV boxes shall be used for perimeter zone applications only. VAV shutoff boxes shall be used only with the perimeter air distribution systems in order to eliminate the need for reheat. The air-handling unit and associated VAV boxes shall have self-contained microprocessor controls capable of connecting to and interoperating with a Direct Digital Control (DDC) Building Automation System.

Variable Volume System with Fan-Powered Boxes. Variable air volume (VAV) systems with fan-powered VAV boxes may be used for both perimeter and interior zone applications. The air-handling unit and associated VAV boxes shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS Direct Digital Control (DDC) Building Automated System. Fan powered boxes shall be equipped with a ducted return, featuring a filter/filter rack assembly and covered on all external exposed sides with two-inches of insulation. The return plenum box shall be a minimum of 61 mm (24 inches) in length and shall be double wall with insulation in-between or contain at least one elbow where space allows. Fan-powered boxes may have hot water heating coils used for maintaining temperature conditions in the space under partial load conditions. Fan powered boxes located on the perimeter zones and on the top floor of the building shall contain hot water coils for heating.

Underfloor Air Distribution System. Underfloor air distribution systems shall incorporate variable air volume (VAV) units designed to distribute the supply air from under the floor using variable volume boxes or variable volume dampers running out from underfloor, ducted, main trunk lines. Air shall be distributed into the space through floor-mounted supply registers that shall be factory fabricated with manual volume control dampers. Supply air temperature for underfloor systems shall be between 10°C (50°F) dew point and 18°C (64°F) dry bulb. For perimeter underfloor systems, provide fan coil units or fin tube radiators located beneath the floor with supply air grilles or registers mounted in the floor.
The air-handling unit, VAV boxes, and variable volume dampers shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS direct digital control (DDC) Building Automation System. The maximum zone size of an underfloor air distribution system shall not exceed 2,360 l/s (5,000 CFM).

Underfloor Air Displacement System. Underfloor air displacement systems shall incorporate variable air volume (VAV) units designed to distribute the supply air from under the floor using variable volume boxes or variable volume dampers running out from underfloor, ducted, main trunk lines. The VAV boxes or control dampers shall be hard ducted or connected directly to the main trunk lines. Air shall be distributed into the occupied space through floor-mounted, low-turbulence, displacement flow, swirl diffusers and shall contain a dust collection basket situated below the floor. Supply air temperature for underfloor systems shall be 10°C (50°F) dew point and 18°C (64°F) Dry Bulb. For perimeter underfloor systems, provide fan coil units or fin tube radiators located beneath the floor with supply air grilles or registers mounted in the floor. The air-handling unit, VAV boxes, and variable volume dampers shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS Direct Digital Control (DDC) Building Automation System. The maximum capacity of an underfloor air distribution system shall not exceed 2,360 l/s (5,000 cfm).

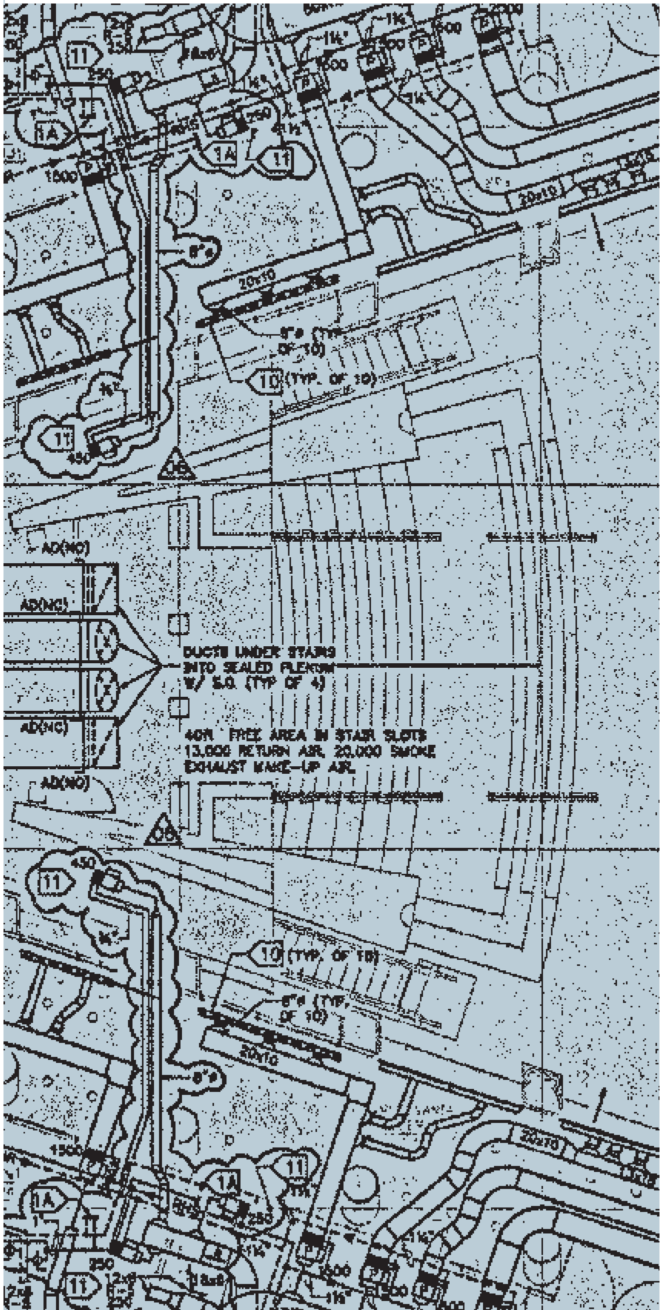
Heat Pump Systems. Console perimeter heat pump system(s) may be considered for the perimeter zone. For the interior zone either a packaged heat pump variable volume system or a central station air handling unit with cooling-heating coil with VAV boxes shall be considered. Condenser water loop temperatures shall be maintained between 15°C (60°F) and 27°C (80°F) year round, either by injecting heat from a gas fired, modular boiler if the temperature drops below 15°C (60°F) or by rejecting the heat through a cooling tower if the temperature of the loop rises above 35°C (95°F) dry bulb. Outside air shall be ducted to the return plenum section of the heat pump unit. Heat pumps shall be provided with filter/filter rack assemblies upstream of the return plenum section of the air-handling unit.

HVAC System Components

Air-Handling Units (AHU's). Air-handling units shall be sized to not exceed 11,800 l/s (25,000 cfm). Smaller units are encouraged to facilitate flexible zone control, particularly for spaces that involve off-hour or high-load operating conditions. To the extent possible, "plug-n-play" AHU configurations should be considered, facilitating easy future adaptations to space-load changes. Psychrometric analyses (complete with chart diagrams) shall be prepared for each air-handling unit application, characterizing full and part load operating conditions. Air-handling unit/coil designs shall assure that conditioned space temperatures and humidity levels are within an acceptable range, per programmed requirements, and ASHRAE Standards 55 and 62.

Depending on sensible heat ratio characteristics, effective moisture control may require cooling coil air discharge dew point temperatures as low as 10°C (50°F). As required, provide face-by-pass or heat recovery features to re-heat cooling coil discharge temperatures for acceptable space entry. Provide a direct form of re-heat and/or humidification only if space conditions require tight environmental control, or if recurring day-long periods of unacceptable humidity levels would otherwise result.

Supply, Return and Relief Air Fans: Centrifugal double-width double-inlet forward curved and airfoil fans are preferable 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 required horsepower as well as sound power level ratings at full load and at part load conditions. Fan motors shall be sized so they do not run at overload anywhere on their operating curve. Fan operating characteristics must be checked for the entire



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range of flow conditions, particularly for forward curved fans. 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.

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 that the coils can be effectively and efficiently cleaned. Dehumidifying coils shall be selected for no more than negligible water droplet carryover beyond the drain pan at design conditions. All hot water heating and chilled water cooling coils shall be copper tube and copper finned materials. Equipment and other obstructions in the air stream shall be located sufficiently downstream of the coil so that it will not come in contact with the water droplet carryover. Cooling coils shall be selected at or below 2.5 m/s 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 shall be made of stainless steel, insulated and adequately sloped and trapped to assure drainage. Drains in draw-through configurations shall have traps with a depth and height differential between inlet and outlet equal to the design static pressure plus 2.54 mm (1 inch) minimum.

Filter Sections: 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 filters with 85 percent efficiency capable of filtering down to 3.0 microns per *ASHRAE 52.* 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 face velocity. 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 and sensors shall be placed across each filter bank to allow quick and accurate assessment of filter dust loading as reflected by air-pressure loss through the filter and sensors shall be connected to building automation system.

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

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

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

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

Terminals. *VAV terminals* shall be certified under the ARI Standard 880 Certification Program and shall carry the ARI Seal. If fan-powered, the terminals shall be designed, built, and tested as a single unit including motor and fan assembly, primary air damper assembly and any accessories.

VAV terminals shall be pressure-independent type units.

Units shall have BACnet or LONWORKS self-contained controls.

Fan-powered terminals: Fan-powered terminals shall utilize speed control to allow for continuous fan speed adjustment 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 the 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 m3/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 expected variation in range in the outlet air volume to ensure the air diffusion performance index (ADPI) values remain above a specified minimum. This is achieved by low temperature variation, 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.

Motors. All motors shall have premium efficiency as per *ASHRAE 90.1*. 1/2 HP and larger shall be polyphase. Motors smaller than 1/2 HP shall be single phase. For motors operated with variable speed drives, provide insulation cooling characteristics as per NEC and NFPA.

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 breeching, flue stack and combustion air. For northern climates, a minimum of three equally sized units shall be provided. Each of the three units shall have equal capacities such that the combined capacity of the three boilers shall satisfy 120 percent of the total peak load of heating and humidification requirements. For southern climates, a minimum of two equally sized units at 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. Multiple closet type condensing boilers shall be utilized, if possible. Boilers shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS Direct Digital Control (DDC) Building Automated System. Boilers shall have a minimum efficiency of 80 percent as per *ASHRAE 90.1.*

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.

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

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

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

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

Heat Exchangers. Steam-to-water heat exchangers shall be used in situations where district steam is supplied and a hot water space heating and domestic hot water heating system have been selected. Double-wall heat exchangers shall be used in domestic hot water heating applications. Plate heat exchangers shall be used for waterside economizer applications.

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, ice storage chillers, and absorption chillers should be considered for demand shedding and thermal balancing of the total system.

BACnet or LONWORKS Microprocessor-based controls shall be used. The control panel shall have self-diagnostic capability, integral safety control and set point 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: When the peak cooling load is 1760 kw (500 tons) or more, a minimum of three chilled water machines shall be provided. The three units shall have a combined capacity of 120 percent of the total peak cooling load with load split percentages 40-40-40 or 50-50-20. If the peak cooling load is less than 1760 kW (500 tons), a minimum of two equally sized machines at 67 percent of the peak capacity (each) shall be provided. All units shall have adequate valving to provide isolation of the off-line unit without interruption of service. Cooling systems with a capacity less than 50 tons shall use air-cooled chillers.

Chillers shall be piped to a common chilled water header with provisions to sequence chillers on-line to match the load requirements. All required auxiliaries for the chiller systems shall be provided with expansion tanks, heat exchangers, water treatment and air separators, as required. If multiple chillers are used, automatic shutoff valves shall be provided for each chiller.

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

Chiller condenser piping shall be equipped with recirculation/bypass control valves to maintain incoming condenser water temperature within chiller manufacturer's minimum.

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

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

Chlorofluorocarbon (CFC) refrigerants are not permitted in new chillers. 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 these 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.

Ice Storage Equipment. Ice-on-coil systems shall be considered in locations where the demand costs of electricity are greater than $15.00 per kW (demand costs for peak generation, transmission, and delivery costs), including prefabricated tanks with glycol coils and water inside the tank. The tank shall be insulated and its capacity and performance shall be guaranteed by the vendor. Self-contained, fabricated ice storage system shall have self-contained BACnet LONWORKS microprocessor controls for charging and discharging the ice storage system and capable of being connected to a central building automation system. Other types of ice storage systems are not permitted.

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

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

Forced draft towers shall have inlet screens. Forced draft towers shall have directional discharge plenums where required for space or directional considerations. 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 tower basins and housing shall be constructed of stainless steel. If the cooling tower is located on the building structure, vibration and sound isolation must be provided. Cooling towers shall be elevated to maintain required net positive suction head on condenser water pumps and to provide a 4-foot minimum clear space beneath the bottom of the lowest structural member, piping or sump, to allow re-roofing beneath the tower.

Special consideration should be given to de-icing cooling tower fills if they are to operate in sub-freezing weather, such as chilled water systems designed with a water-side economizer. A manual shutdown for the fan shall be provided. If cooling towers operate intermittently during sub-freezing weather, provisions shall be made for draining all piping during periods of shutdown. For this purpose indoor drain down basins are preferred to heated wet basins at the cooling tower. Cooling towers with waterside economizers and designed for year-round operation shall be equipped with basin heaters. Condenser water piping located above-grade and down to 3 feet below grade shall have heat tracing. Cooling towers shall be provided with BACnet LONWORKS microprocessor controls, capable of connecting to central building automation systems.

Chilled Water, Hot Water, and Condenser Water Pumps. Pumps shall be of a centrifugal type and shall generally be selected to operate at 1750 RPM. Both partial load and full load must fall on the pump curve. The number of primary chilled water and condenser water pumps shall correspond to the number of chillers, and a 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 throughout the entire range of the pump curve. Each pump system shall have a standby capability for chilled, hot water, and condenser water pumps.

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

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

5.10 Humidification and Water Treatment

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

Humidification shall be limited to building areas requiring special conditions. Courtrooms with wall coverings of wood shall be provided with humidification. General office space shall not be humidified unless severe winter conditions are likely to cause indoor relative humidity to fall below 30 percent. Where humidification is necessary, atomized hot water, clean steam or ultrasound may be used and shall be generated by electronic or steam-to-steam generators. To avoid the potential for oversaturation and condensation at low load, the total humidification load shall be divided between multiple, independently-modulated units. Single-unit humidifiers are not acceptable. When steam is required during summer seasons for humidification or sterilization, a separate clean steam generator shall be provided and sized for the seasonal load. Humidifiers shall be centered on the air stream to prevent stratification of the moist air. All associated equipment and piping shall be stainless steel. Humidification system shall have microprocessor controls and the capability to connect to building automation systems.

Water Treatment. The water treatment for all hydronic systems, including humidification systems, shall be designed by a qualified specialist. The design system shall address the three aspects of water treatment: biological growth, dissolved solids and scaling, and corrosion protection. The performance of the water treatment systems shall produce, as a minimum, the following characteristics; hardness: 0.00; iron content: 0.00; dissolved solids: 1,500 to 1,750 ppm; silica: 610 ppm or less; and a PH of 10.5 or above. The system shall operate with an injection pump transferring chemicals from solution tank(s) as required to maintain the conditions described. The chemical feed system shall have self-contained microprocessor controls capable of connecting to and interoperating with a Direct Digital Control (DDC) Building Automation System. The methods used to treat the systems' make-up water shall have prior success in existing facilities on the same municipal water supply and follow the guidelines outlined in *ASHRAE Applications Handbook.*

5.11 Heating Systems

College Park, MD

Steam Heating

District steam heating, if available, shall be used 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 in the mechanical room near the entrance into the building. If steam heating is used, the designer shall investigate the use of district steam condensate for pre-heating of domestic hot water. Steam heating is not permitted inside the building other than conversion of steam-to-hot water in the mechanical room.

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

Steam delivered from any source other than a clean steam generation system shall be prohibited from use in providing humidification. Steam delivered from a central plant, a district steam system, steam boilers, or any equipment where chemicals are delivered into the medium resulting in the final product of steam shall not be used for the purpose of providing humidification to the HVAC system or occupied spaces.

Hot Water Heating Systems

GSA prefers low-temperature hot-water heating systems; 205 kPa (30 psi) working pressure and maximum temperature limitation of 93.3°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 *"Humidification and Water Treatment"* of this chapter for water treatment.

Temperature and Pressure Drop. Supply temperatures and the corresponding temperature drops for space heating hot water systems must be set to best suit the equipment being served. Total system temperature drop should not exceed 22°C (72°F). The temperature drop for terminal unit heating coils shall be 11°C (52°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, and not less than 1.3 meters per second (4 feet per second).

Freeze Protection. Propylene 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. Freeze protection circulation pump shall be provided along with polypropylene glycol. Heat tracing systems are not acceptable for systems inside the building. Glycol solutions shall not be used directly in boilers, because of corrosion caused by the chemical breakdown of the glycol. The water make-up line for glycol systems shall be provided with an in-line water meter to monitor and maintain the proper percentage of glycol in the system. Provisions shall be made for drain down, storage and re-injection of the glycol into the system.

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

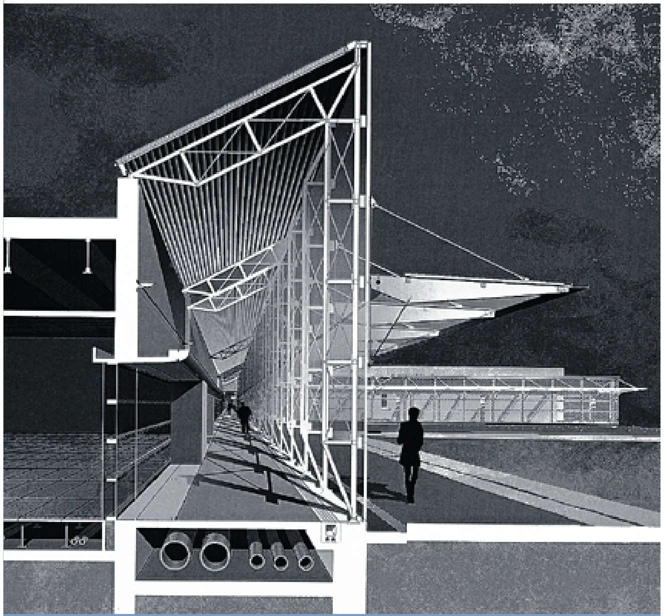
Instantaneous Hot Water. The use of instantaneous hot water generators is prohibited except for incidental use at terminal fixtures.

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.

5.12 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 10°C (50°F) temperature differential in the central system, at the central plant, with a design supply water temperature between 4°C and 7°C (40°F and 45°F). In climates with low relative humidity, an 8°C (46°F) may be used. The chilled water system shall have a 6°C (43°F) temperature differential in the secondary systems, at the terminal points of use, such as coils with a design supply water temperature between 4°C and 7°C (40°F and 45°F).

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

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.

Freeze Protection. Propylene 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 exposed to 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 condensers must be connected to a recirculating heat-rejecting loop. The heat rejection loop system shall be designed for a 6°C (43°F) temperature differential and a minimum of 4°C (40°F) wet bulb approach between the outside air temperature and the temperature of the water leaving the heat rejection equipment. Heat tracing shall be provided for piping exposed to weather and for piping down to 3 feet below grade.

Water Treatment. See section: *Humidification and Water Treatment* of this chapter for water treatment.

Special Cooling Systems

Waterside Economizer Cycle. In certain climate conditions cooling towers are capable of producing condenser water cold enough to cool the chilled water system without chiller operation. This option shall be considered in life cycle cost comparisons of water cooled chillers. Waterside economizer cycles are particularly cost effective in the low humidity climates of the western United States. In the eastern United States, enthalpy airside economizer cycles tend to produce lower operating costs. However, where used, any airside economizer shall be set so that no air with a dew point above 10°C (50°F) is allowed into the building. Waterside economizer systems shall be used only in areas where the outside air temperature will be below 4.4°C (40°F) wet bulb. Waterside economizers shall utilize a plate heat exchanger piped in parallel arrangement with its respective chiller. See "*Air Distribution Systems, Air-Handling Units, and Airside 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 shall be specifically designed for this purpose and contain compressors, filters, humidifiers and controls. They shall be sized to allow for a minimum of 50 percent redundancy, either two units at 75 percent load or three units at 50 percent. If the nature of the computer room is critical (as determined by consulting the GSA's Office of the Chief Information Officer), three units sized at 50 percent of the design load shall be used. Heat rejection from these self-contained units shall be by air-cooled condensers or recirculating water-cooled condensers connected to a cooling tower or evaporative-cooled condenser. Water-side free cooling shall be utilized when possible.

For cooling loads greater than 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.

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

For ventilation, air-handling, and humidification requirements of computer rooms, see sections *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. 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.

Desiccant Cooling. For high occupancy applications where moisture removal is required, solid desiccant with silica gel may be used in combination with mechanical cooling. Heat recovery wheels may be used prior to the mechanical cooling process. Desiccant cooling units shall be equipped with airflow-setting devices for both process and reactivation air flows, and shall be equipped with gauges or digital displays to report those air flows continuously. The desiccant cooling system shall have self-contained microprocessor controls capable of connecting to and interoperating with a direct digital control (DDC) Building Automation system. Natural gas or condenser waste heat shall be used as fuel for reactivation of the desiccant. Lithium chloride liquid desiccants are not permitted.

5.13 Heat Recovery Systems

Heat recovery systems shall be utilized in all ventilation units (100 percent outside air units) and where the temperature differentials between supply air and exhaust air is significant. Heat recovery systems shall operate at a minimum of 70 percent efficiency. The heat recovery systems must be capable of connecting to a microprocessor controller that in turn can be connected to a direct digital control (DDC) Building Automation System. Prefilters shall be provided in all heat recovery systems before the heat recovery equipment.

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

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

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

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

5.14 Pressurization and Ventilation

Pressurization

Perimeter Zone. A dedicated 100 percent outside air unit shall be used to maintain positive pressure. The ventilation air for the perimeter air-handling unit shall be sized based on maximum occupancy with diversity and shall operate continuously during occupied hours and operate at 40 percent capacity during unoccupied hours. Industrial grade pressure sensors shall be located at several perimeter areas to communicate outside air pressure to maintain differential positive pressure (adjustable). The internal pressure need only be slightly higher than ambient on average to achieve the goal of excluding humid outdoor air from building cavities. In any case, internal pressure shall not be greater than 10 pascals. Maintain supply air discharge at the unit no more than 10°C (50°F) dewpoint when outside air dewpoint is above this temperature. Maintain neutral pressure ($\Delta P=0$) when the outdoor ambient temperature falls below 3°C(37°F) dewpoint and neutral pressure. Differential pressure sensors and dewpoint sensors shall be connected to the building automation system. An alarm shall signal if positive or neutral pressures are not maintained, on average, based on multiple samples taken within a five-minute period. Only industrial grade sensors are permitted.

Interior Zone. A dedicated outside air-handling unit shall be used to maintain positive pressure. The unit shall be sized based on the fresh air requirements for maximum occupancy with diversity. The unit shall have air-monitoring devices and control the exhaust rate during occupied hours to be less than 10 percent of the supply "air to ensure positive pressure in the space. The unit shall shut down during unoccupied hours. Maintain 10°C (50°F) dewpoint when outside air dewpoint is above that of the outside air. Use humidification equipment, if necessary, to maintain 3°C (37°F) dewpoint whenever outside dewpoint is below 3°C (37°F). Also maintain neutral pressure by setting the exhaust air quantity to equal the supply air rate. Air monitoring devices shall be connected to the building automation system to indicate positive and neutral pressure.

Special Ventilation Requirements

Ventilation requirements for all building spaces shall comply with *ASHRAE 62*.

Entrance Vestibules and Lobbies. Sufficient heating and cooling should be provided to offset the base load plus the infiltration load of the space. The entrance vestibule should be positively pressurized relative to atmospheric pressure to minimize infiltration. A separate variable air volume (VAV) system shall serve entrance vestibules and lobby spaces. The VAV system shall operate to vary the flow of air for the space through a differential pressure control system designed to maintain positive pressure relative to the outdoors and neutral or negative pressure relative to adjacent spaces. Also provide air monitoring devices in the unit. The air-handling unit and the variable volume dampers at the VAV boxes shall have self-contained microprocessor controls capable of connecting to and interoperating with a BACnet or LONWORKS direct digital control (DDC) Building Automation System.

Atriums. A dedicated air-handling system shall be provided to control heat gain/loss in the occupiable areas of the atrium. The atrium area should maintain negative pressure relative to adjacent interior and perimeter spaces or zones and positive or neutral pressure relative to adjacent vestibules and lobbies, and positive pressure relative to the outdoors. The design of the HVAC system must be fully coordinated with the smoke control system.

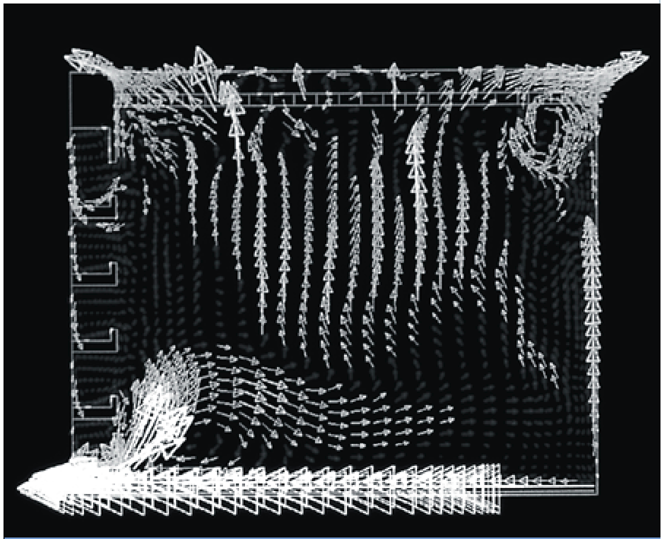
Toilets. Toilet areas must have segregated exhausts and should be negative in pressure relative to surrounding spaces.

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 CO_2 demand controlled ventilation (DCV) system to minimize energy consumption, while maintaining appropriate levels of ventilation and pressure relationships between spaces and the outdoors. The DCV system devices shall be located for ease of maintenance and shall provide appropriate operation of the ventilation system it is controlling. Enthalpy heat recovery system shall be utilized if economically feasible.

5.15 Air Distribution Systems



Air Flow Diagram, Atrium, Phoenix Courthouse

Variable Air Volume (VAV) Systems

The VAV supply fan shall be designed for the largest block load, not the sum of the individual peaks. The air distribution system up to the VAV boxes shall be medium pressure and shall be designed by using the static regain method. Downstream of the VAV boxes the system shall be low and medium pressure construction and shall be designed using the equal friction method. Sound lining is not permitted. Double wall ductwork with insulation in-between is permitted in lieu of sound lining. All VAV boxes shall be accessible for maintenance. Ducted return shall be utilized at all locations. VAV fan-powered box supply and return ducts shall have double wall ductwork with insulation in-between for a minimum distance of 5 feet.

Underfloor Air Distribution Systems. Provide plenum zones both for perimeter and interior in order to control the underfloor variable volume dampers or boxes with separate plenum barriers between perimeter and interior zones. The underfloor plenum shall be air tight and compartmentalized with baffles. Provisions shall be provided for cleaning the plenum space. When underfloor supply air distribution is used, the ceiling plenum shall be used for the distribution of the ducted return air. The perimeter and interior underfloor zones shall be clearly separated in order to maintain proper pressurization, temperature and humidity control. Zoning of the underfloor air distribution systems shall be in accordance with descriptions presented elsewhere in this chapter. Perimeter wall below the raised flooring system shall be provided with R-30 insulation and vapor barrier below the raised floor. All VAV boxes that are part of an underfloor air distribution system for both perimeter and interior systems shall be located below the raised floor. The floor area used for an underfloor system shall have the slab provided with a minimum of R-10 insulation and vapor barrier from below. This shall incorporate the entire slab area used for the underfloor system.

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. Terminal air volume control devices are 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. If ventilation air is delivered through the VAV box, the minimum volume setting of the VAV box should equal the larger of the following:

1. 30 percent of the peak supply volume;
2. 0.002 m3/s per m2 (0.4 cfm/sf) of conditioned zone area; or
3. Minimum m3/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 air flow conditions.

Airside Economizer Cycle. An air-side enthalpy economizer cycle reduces cooling costs when outdoor air enthalpy is below a preset high temperature limit, usually 15 to 21°C (60°F to 70°F), depending on the humidity of the outside air. Airside economizers shall only be used when they can deliver air conditions leaving the air-handling unit of a maximum of 10°C (50°F) dewpoint and a maximum of 70 percent relative humidity. Enthalpy economizers shall operate only when return air enthalpy is greater than the outside air enthalpy.

All air distributions systems with a capacity greater than 1,416 LPS (3,000 CFM) shall have an air-side economizer in accordance with *ASHRAE 90.1*, unless the design of the air handling systems preclude the use of an airside economizer.

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.* All ductwork joints and all connections to air handling and air distribution devices shall be sealed with mastic—including all supply and return ducts, any ceiling plenums used as ducts and all exhaust ducts. Energy consumption, security and sound attenuation shall be major considerations in the routing, sizing and material selection for the air distribution ductwork.

Supply, Return and Exhaust Ductwork

Ductwork Pressure. Table 5-3 provides pressure classification and maximum air velocities for all ductwork. Ductwork construction shall be tested for leakage prior to installation. Each section tested must have a minimum of a 20 ft. length straight-run, a minimum of two elbows and a connection to the terminal. The stated static pressures represent the pressure exerted on the duct system and not the total static pressure developed by the supply fan. The actual design air velocity 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 main to terminal boxes and distribution devices) shall be low pressure classification as a minimum.

Supply, return and exhaust air ducts shall be designed and constructed to allow no more than 3 percent leakage of total airflow in systems up to 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.

Pressure loss in ductwork shall be designed to comply with the criteria stated above. This can be accomplished by using smooth transitions and elbows with a radius of at least 1.5 times the radius of the duct. Where mitered elbows have to be used, double foil sound attenuating turning vanes shall be provided. Mitered elbows are not permitted where duct velocity exceeds 10m/s (2000 FPM).

Sizing of Ductwork. Supply and return ductwork shall be sized using the equal friction method except for ductwork upstream of VAV boxes. Duct systems designed using the

Table 5-3
Ductwork Classification

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

Table 5-4
Recommended Duct Velocities

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

equal friction method place enough static pressure capacity in the supply and return fans to compensate for improper field installation and changes made to the system layout in the future. In buildings with large areas of open plan space, the main duct size shall be increased for revisions in the future. Air flow diversity shall also be a sizing criterion. 80 percent diversity can be taken at the air-handling unit and decreased the farther the ductwork is from the source until air flow diversity is reduced to zero for the final portion of the system.

Ductwork Construction. Ductwork shall be fabricated from galvanized steel, aluminum or stainless steel sheet metal depending on applications. Flex duct may be used for low pressure ductwork downstream of the terminal box in office spaces. The length of the flex duct shall not exceed the distance between the low pressure supply air duct and the diffuser plus 20 percent to permit relocation of diffusers in the future while minimizing replacement or modification of the hard ductwork distribution system. 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. Use of pressure sensitive tape is not permitted.

Kitchen Ventilation Systems. Products of combustion from kitchen cooking equipment and appliances shall be delivered outside of building through the use of kitchen ventilation systems involving exhaust hoods, grease ducts and make-up air systems where required. Commercial kitchen equipment applications shall be served by a Type I hood constructed in compliance with UL 710 and designed in accordance with code having jurisdiction. Grease ducts shall be constructed of black steel not less than 0.055 inch (1.4 mm) (No. 16 gauge) in thickness or stainless steel not less than 0.044 inch (1.1 mm) (No. 18 gauge in thickness).

Make-up air systems serving kitchen exhaust hoods shall incorporate air-side heat exchange to recover energy from the exhaust stream to be used for heating the supply air stream.

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

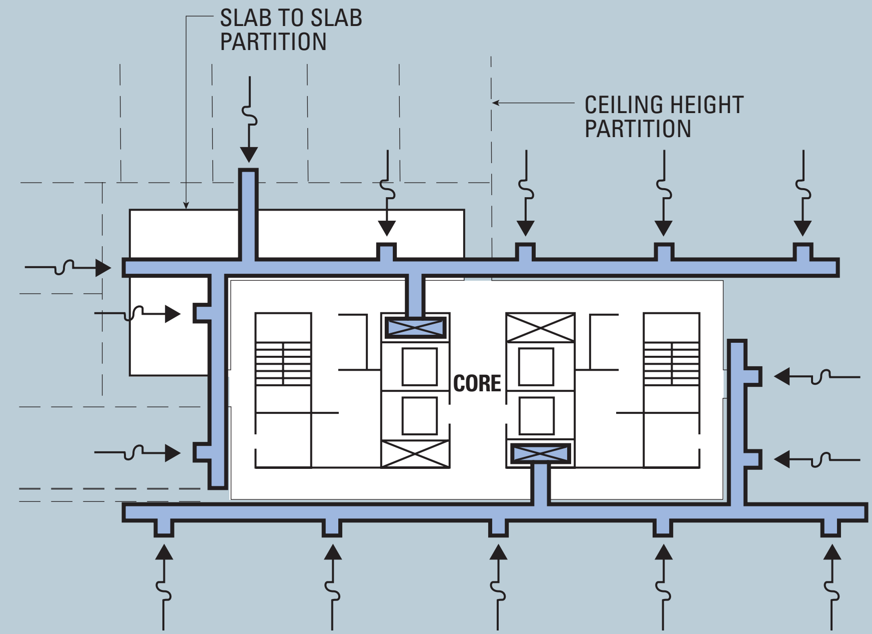
Raised Floor Plenum Supply. In computer rooms, underfloor plenum supplies are appropriate. As a general application in other areas (e.g. open offices), underfloor air distribution/displacement systems are appropriate. Where raised floor plenums are used for supply air distribution, the plenums shall be properly sealed to minimize leakage. R-30 insulation with vapor barrier shall be provided for perimeter of raised floor walls.

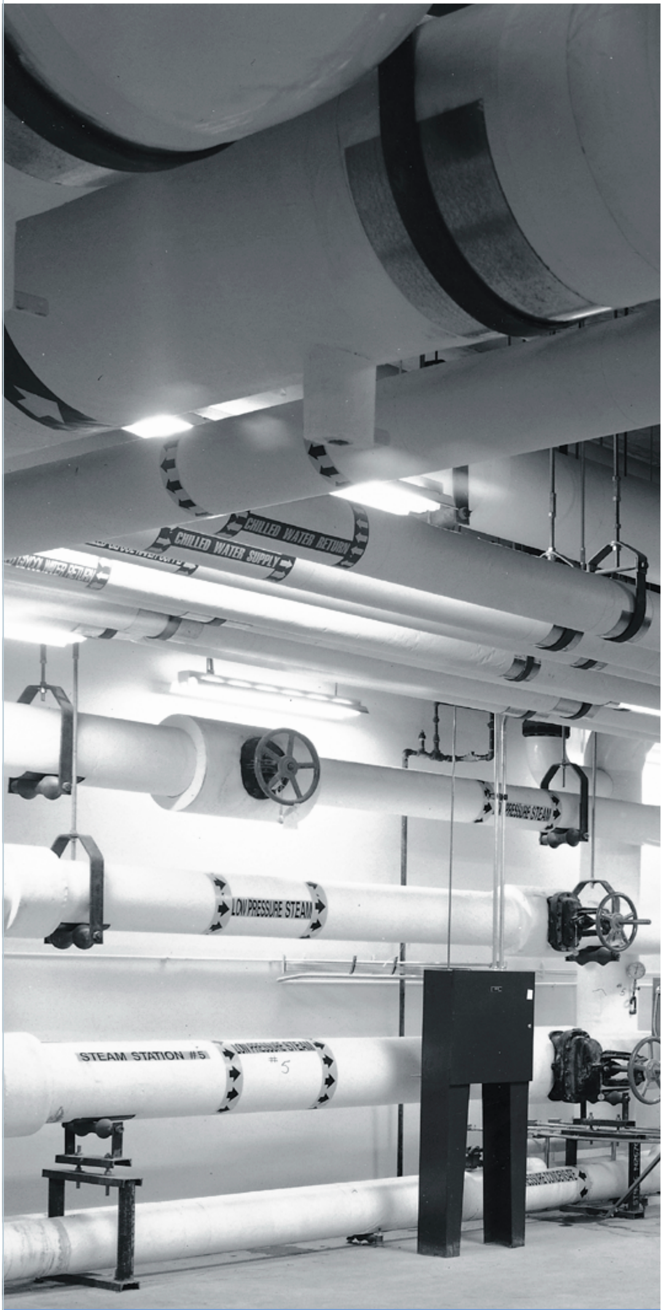
Plenum and Ducted Returns. With a return plenum care must be taken to ensure that the air drawn through the most remote register actually reaches the air-handling unit. The horizontal distance from the farthest point in the plenum to a return duct shall not exceed 15 m (50 feet). No more than 0.8 m3/s (2,000 cfm) should be collected at any one return grille. Figure 5-2 illustrates an example of an open ceiling plenum with return air ductwork. Return air plenums should be avoided. When deemed necessary for economic reasons, plenums shall be sealed air-tight with respect to the exterior wall and roof slab or ceiling deck to avoid creating negative air pressure in exterior wall cavities that would allow intrusion of untreated outdoor air. All central multi-floor-type return air risers must be ducted.

Other less flexible building spaces, such as 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.

Return air duct in the ceiling plenum of the floor below the roof shall be insulated. Double wall ductwork with insulation in-between shall be used in lieu of sound lining for a minimum of the last 5 feet before connecting to the air handling unit or a return air duct riser.

Figure 5-2 Ceiling Return Plenum with Minimal Return Ductwork





College Park, Maryland chilled water supply and return

5.16 Pumping Systems

Pump and Piping Systems. The 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 shall be equipped with automatic flow control valves at terminal units (all types of heat transfer units). Reverse return is considered 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 pipe branches, such as at each floor level, building wing or mechanical room.

Each pumping system shall be provided with two pumps, one operating while the other is in standby mode. These pumps shall be configured for automatic lead/ lag operation.

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 shall be provided 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.

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 all times.

Flow may be varied by variable speed pumps or staged multiple pumps. Pumps should operate at no less than 75 percent efficiency on their performance curve. Variable flow pumping must be designed carefully. Package systems should be used, complete with pumps and controls factory-tested 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.

5.17 Piping Systems

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

Chilled Water and Condenser Water 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 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.

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 if required by the Geotechnical Report.

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

Isolation of Piping at Equipment. Isolation valves, shutoff valves, by-pass circuits, flanges 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 Supports. Provide channel supports for multiple pipes and heavy duty steel trapezes to support multiple pipes. Hanger and support schedule shall have manufacturer's number, type and location. Comply with MSS SP69 for pipe hanger selections. Spring hangers and supports shall be provided in all the mechanical rooms.

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

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

Table 5-5
Commercial Standards for Piping Material

Standard Piping Material	Use	Comments
ASTM Schedule 40	Chilled water up to 300 mm (12-in) dia., Condenser water up to 300 mm (12-in) dia.	1035 kPa (150 psi) fittings. Standard weight pipe over 300 mm (12-in) diameter.
	Hot water	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 Refrigeration Cast Iron Sanitary, waste and vent Storm	Lead-free solder connections. Type ACR.

5.18 Thermal Insulation

General

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 and tapes shall have the same or better fire and smoke hazard ratings.

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). Insulation shall have zero permeability.

Duct Insulation. 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. Ductwork with double wall construction having insulation in-between shall only be used for courtroom return air transfer grilles, and only if required for acoustic purposes. All exposed ductwork shall have sealed canvas jacketing. All concealed ductwork shall have foil face jacketing.

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

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

Piping Insulation. All insulation material shall comply with the fire and smoke hazard ratings indicated by ASTM-E84, NFPA 255 and UL 723. Accessories such as adhesives, mastics, cements, tapes, etc. shall have the same or better component ratings. All piping systems must be insulated in accordance with *ASHRAE Standard 90.1*. Piping systems conveying fluids, 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. All exposed and concealed piping shall have PVC jacketing.

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

Thermal Pipe Insulation for Plumbing Systems

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

Domestic water piping shall be insulated in accordance with *ASHRAE 90.1*.

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

5.19 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 Shafts and Chases. Mechanical shafts and 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. Shafts dedicated to gas piping must be ventilated.

Acoustical criteria for all building spaces are described in Chapter 3: *Architectural and Interior Design, Special Design Considerations, Acoustics*. For HVAC noise levels refer to Table 3-4, "Design Guidelines for HVAC-Related Background Sound in Rooms."

Also, for design criteria, refer to "Selection Guide for Vibration Isolation," *ASHRAE 99 Application Handbook, Chapter 46*.

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-generated noise 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. All ductwork connections to equipment having motors or rotating components shall be made with 6-inch length of flexible connecters. All ductwork within the mechanical room or serving courtrooms shall be supported with isolation hangers.

Piping Hangers and Isolation. Isolation hangers 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 Control in VAV Systems. System sound levels at maximum flow must be carefully evaluated to ensure acoustic levels required in Chapter 3. 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 double wall ductwork with insulation in-between (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.

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

5.20 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. Flow measuring devices shall be capable of communicating with the central BAS. Water flow and air flow measuring devices shall confirm or validate *ASHRAE 90.1* requirements.

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

Water Use Meters. See Section 5.24, *Plumbing Systems, Domestic Water Supply Systems,* in this chapter.

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 all floor areas where vertical shafts penetrate the garage areas.

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

Central Air Handling Units Start/Stop Heating Control Cooling Control Humidification Control Supply Air Reset Static Pressure Reset Building and Zone Pressurization Control Damper Position (economizer) Supply Air Discharge Temp Return Air Temp Mixed Air Temp Supply Air Flow Rate Filter Differential Pressure Air Flow Measuring Station	**Refrigeration Equipment** Start/Stop Leave Water Temp Reset Demand Limiting Isolation Valve Position Leaving Water Temp Entering Water Temp kW Draw Flow Return Air Flow Rate	**Hot Water Boilers** Start/Stop Leaving Water Temp Reset Reset Isolation Valve Position Leaving Water Temp Entering Water Temp Flow BTU Draw
Cooling Towers Start/Stop Leaving Water Temp Reset Flow Isolation Valve Position Entering Water Temp Leaving Water Temp	**Terminal Boxes** Start/Stop Discharge Temp Reset Supply Volume Reset Heating Control Zone Temp Reset Minimum Volume Reset Zone Temp Supply Air Reset Zone Pressurization Control	**Pumps** Start/Stop Discharge Pressure Reset Differential Pressure Flow
Utilities Natural Gas Consumption Electricity Consumption & Demand Water Consumption Fuel Oil Quantity		

5.21 Control Systems

Automatic Temperature and Humidity Controls

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

Control Systems shall be BACnet or LONWORKS, conforming to ASHRAE BACnet Standard 135.

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

PID loops shall be utilized. All chillers, boilers, terminal units and air handling units shall have self-contained BACnet or LONWORKS controllers, capable of communicating with the Building Automation System.

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 perimeter zone.

A 1.5°C (35°F) dead band shall be used between independent heating and cooling operations within the same zone.

Night set-back and set-up controls must be provided for all comfort conditioned spaces, even if initial building occupancy plans are for 24-hour operation. Morning warm-up or cool-down must be part of the control system. Controls for the various operating conditions must include maintaining pressurization requirements.

Humidity Controls. Indoor and outdoor humidity sensors shall be calibrated in-place during system startup and at least annually thereafter. Dew point control is preferred because it tends to provide more stable humidity levels. However, rh sensors are acceptable, provided they have been calibrated in-place, and provided that they have co-located with dry bulb sensors so that the BAS can convert these two signals to a dew point value for control purposes.

Temperature Reset Controls

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

5.22 Building Automation Systems (BAS)

BAS shall be direct digital control (DDC) for providing lower operating costs and ease of operation. Microprocessor PID 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 and lighting.

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

A BAS is not required for every project and should be evaluated based on the size of the building. Buildings of 100,000 gsf. and more shall have a BAS. 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 is required and considered part of the system on large facilities (above 9,300 gross square meters (100,000 gross square feet)), both new facilities and major modernizations.

Level of Integration. 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.

Lighting control systems shall not be connected to BAS except for monitoring of lighting system.

Fire alarm systems, security systems and elevator systems shall not be 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 per *ASHRAE Standard 135*, to minimize the costs of providing integration and to allow interoperability between building systems and control vendors. Other open protocol language systems, such as LonTalk, may also be used, provided there is compatibility with overall regional and/or central monitoring and central strategies. A/E to specify and include functional design manual, hardware manual, software manual, operation manual, and maintenance manual. BAS shall have energy management and monitoring software.

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

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.

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

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

5.23 Startup, Testing, and Balancing Equipment and Systems

Startup. 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 Associated Air Balance Council (AABC), the National Environmental Balance Bureau (NEBB), or the Testing, Adjusting, and Balancing Bureau (TABB).

Performance Testing. A/E to specify performance testing of all equipment and systems including chillers, boilers, and other systems for part load and full load during summer, winter, spring and fall season as per the schedules specified by the designer. A/E to specify the services of an organization certified by NEBB or AABC.

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

A/E to specify IAQ testing for CO, CO2, volatile organic compounds, NO2, O3, and tobacco smoke. A/E to specify operating tests on each air and hydronic system to measure and meet energy efficiency requirements of *ASHRAE 90.1* and 62. A/E to specify and validate peak summer and winter energy consumption and performance.

5.24 Plumbing Systems

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

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. Incoming service shall have double check valves. 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 shall consist of a piping system that 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 Facilities Standards.

Triplex booster pumping system shall be utilized if the water pressure is not adequate to provide sufficient pressure at highest, most remote fixture. The water pressure at the fixture shall be in accordance with the International Plumbing Code.

Hot Water Service. Hot water shall 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.

Instantaneous hot water heaters are not permitted as a primary source. Domestic hot water supply temperature shall be generated at 60°C (140°F), and shall be tempered to 49°C (120°F) using a three-way mixing valve, before supplying to all plumbing fixtures. Hot water supply to dishwashers shall be at 82°C (180°F), and the temperature shall be boosted from 60°C (140ºF) to 82°C (180°F). Heat pump hot water heaters shall be used where possible to save energy. For incidental use, the use of instantaneous hot water heaters is permitted.

Distribution system shall 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 furthest fixture from the heating source 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
- Back flow preventers
- Balancing valves
- Isolation valves
- Hangers and supports
- Thermal insulation

Water hammer arrestors shall be provided at every branch to multiple fixtures and on every floor for both hot and cold water.

Domestic cold and hot water distribution systems shall be insulated per *ASHRAE 90.1 and all exposed piping* shall have PVC jacketing.

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 shall 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.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Sanitary Waste Equipment. Specific drains in kitchen areas shall discharge into a grease interceptor before connecting into the sanitary sewer in accordance with the requirements of 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.

Rainwater Drainage System

Pipe and Fittings. Piping system shall be in compliance with local codes and sized based 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 drains 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.

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 manufactured by companies that are approved by General Services Administration or their representatives.

All fixtures shall have sensing devices for saving water.

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

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. Gas meters shall be located in a gas meter room, thus avoiding leakage concerns and providing direct access to the local gas utility.

All gas piping inside ceiling spaces shall have plenum rated fittings.

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

Duplex fuel-oil pumps with basket strainers and exterior enclosures shall be used for pumping the oil to the fuel burning equipment.

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 system 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.*

5.25 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 up-grade/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 that 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 of 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 a vault for easier access to large mechanical equipment. If equipment cannot be concealed, specify equipment housings in a color that will blend with the historic face. As a last resort, enclose equipment in screening designed to blend visually with the facade.

- Locate equipment with particular care for weight and vibration on older building materials. These materials may not accept the same stress as when the equipment is used in newer construction.

- If new ceilings must be installed, insure that they do not block any light from the top of existing windows or alter the appearance of the building from the 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 doors, 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.