Design and Construction Standards

Division 23 – Heating, Ventilating and Air Conditioning (HVAC)

General

This manual is presented as general guidance. It is for the guidance of mechanical engineers and others in the design and renovation of facilities for Eastern Michigan University (EMU). In order to provide the latitude needed for design, new concepts, etc., deviations may be made from the technical requirements provided professional judgment is made that a safe, adequate, office quality level design will result, and approval is obtained from EMU. Deviations from those requirements included in Public Laws, Federal Regulations, Executive Orders, and similar regulations and users' special requirements are not permitted. This manual contains some, but not all, of the criteria pertinent to the design of HVAC systems for EMU Projects.

Section 23 00 01 Scope of HVAC Design

1. General
    a. Developing complete, accurate, and coordinated contract drawings and specifications is the primary goal of the design and review effort. Design drawings, specifications and calculations shall agree in all respects and they shall be without errors, omissions or deviations from the established criteria.

2. Drawing References
    a. In addition to all HVAC work, the mechanical drawings shall include all interior steam and condensate piping, the building automation system layout, and HVAC control diagrams.
        i. Walk-in refrigerators/freezers in dietetic areas and in laboratories shall be shown on food services drawings.
3. Interdiscipline Coordination : HVAC design must be coordinated with all other disciplines, such as, Architectural, Structural, Electrical, Plumbing and Site Planning. The following HVAC related work is usually shown by other disciplines:
4. Architectural drawings and specifications show all louvers and attached screens in exterior walls, all flashing for ducts and pipes penetrating roofs and exterior walls, finish and identification, painting walls and ceilings, access panels, chases, furred spaces, door grilles, mechanical equipment rooms and penthouses.
5. Structural drawings and specifications show all concrete and structural steel work, including catwalks, concrete housekeeping pads, lintel supports around openings, and platforms for access to HVAC equipment and supports for cooling towers and other large mechanical equipment.
6. Electrical drawings and specifications show motor starters and disconnects not furnished as part of HVAC equipment, smoke detectors (duct and/or space mounted), all power wiring to HVAC smoke dampers, motors, heating cable, controls for winterizing piping, day tank and oil piping in the emergency generator room, and muffler exhaust pipe for emergency generator.

7. Plumbing provides all domestic water make-up supply and drain outlets, underground oil storage tank(s) and piping for emergency generators.
8. Food service and laboratory equipment, shown on Architectural drawings, include all controlled temperature rooms in laboratories and all hoods in dietetic areas, laboratories, and research areas.

Section 23 00 02 Drawings

The following information shall be shown on mechanical HVAC drawings.

1. HVAC system design including indoor steam piping.
2. Seismic design related to the HVAC systems.
3. Walk-in refrigerators and freezers.
4. Outdoor exposed (or, underground) chilled water piping.
5. The HVAC system design documentation shall use EMU standard symbols, abbreviations, standard details, and equipment schedules.
6. In the final design drawings (Construction Documents Phase) all ductwork, regardless of sizes and/or complexity of layout(s), and piping 6" and above shall be shown in double line with all fittings and accessories clearly shown and identified.

Section 23 00 03 Climatic Conditions

The outdoor climatic conditions shall be based on local climatic conditions. These conditions are based on the weather data listed in the latest edition of the ASHRAE Handbook of Fundamentals. The local professional engineers may recommend more severe outdoor climatic conditions, commonly used by them, for review and approval by EMU.

Section 23 00 04 Engineering Economic Analysis

To comply with Public Law 95-619, engineering economic analysis shall be performed, in accordance with the procedure outlined by the Department of Energy (DOE) in National Institute of Standards and Technology (NIST) Handbook 135 (Life Cycle Cost Federal Energy Management Program), to select the most cost effective HVAC system for the application. The additional features of the analysis are:

1. For comparison of systems, a 20 year life cycle shall be assumed.
2. The analysis may be performed by means of available public domain programs, such as, "TRACE", "E-CUBE", and CARRIER E20-II, etc.
3. No taxes or insurance shall be used in computing annual owning cost.

Section 23 00 05 Basic Design Parameters

1. Climatic Criteria
    a. The capacity calculations for the HVAC systems shall be based on the outdoor climatic conditions identified in the latest edition of ASHRAE Fundamentals. The designer shall use the following values:
        i. Summer: 1 percent design dry bulb and wet bulb temperatures.

ii. Winter: 99 percent design dry bulb temperature.
iii. The specified design wet-bulb temperature for cooling tower shall be 78 °F WG.

2. Indoor Design Conditions Degree F Dry Bulb and Percent Relative Humidity

Table 2 - Indoor Design Conditions				
	Summer		**Winter**	
Room or Area	**Db** °F	**%RH**	**Db** °F	**%RH**
Offices, Conference Rooms, Lounges	75	50	72	30
Computer Room(s)	70	40(+5)	70	40(+5)
Electrical Equipment Rooms	104 Maximum	-	50	-
Elevator Machine Rooms	104 Maximum	-	50	-
Telephone Equipment Rooms	65 - 75	40-60	65 - 75	40-60
Toilets	78	--	70	--
Transformer Rooms	Same as Electrical Equipment Room			
Animal Research (Animal Rooms)	65	60 (±5)	85	30 (+5)
Auditoriums	76	60	72	--
Computer Rooms	70	40 (±5)	70	40 (±5)
Dining Rooms	78	50	72	30
Dry Labs	78	50	72	30
Emergency Generator	110	--	40	--
Kitchens	82	60	70	--
Laboratories	76	50	72	30
Locker Rooms	78	50	72	30
Lounges	78	50	72	30
Mechanical Equipment Rooms	Ventilation Only		50	--
Examination	76	50	78	30
Gymnasium	76	50	72	30
Therapeutic	80-85	--	85	--
Warehouse	Ventilation Only		60	--

a. Notes on Indoor Design Conditions:
i. The indoor design conditions are not operating limits. All room thermostats shall be adjustable between 60 °F and 85 °F with an adjustable dead band.
ii. **Single toilets do not require individual room temperature controls in cooling mode.** For exterior single toilets, thermostatically controlled heating terminal devices should be provided to maintain space temperature in winter mode. For common (public) toilets, involving multiple water closets and urinals, room temperature control is required in heating and cooling modes.

iii. Offices, subsistence storage rooms and pharmaceuticals located in warehouses shall be mechanically cooled to maintain 78 degrees F in summer.

3. Outdoor Air Requirements (Mechanical Cooling)
   a. 100 Percent Outdoor Air Areas:
      i. Animal research areas.
      ii. Laboratories.
4. Supply Air Requirements (Mechanical Cooling)
   a. The supply air volume shall be established to meet the cooling load requirements of the occupied space. The supply air volume shall be altered, if required, to meet any exhaust requirement.
   b. If the HVAC system selection includes an all air, variable air volume (VAV) system, the supply air volume, during part load conditions, shall be established to ensure stable performance of the supply, and more so, the return air fans. The reasons for this requirement are:
      i. EMU's selected sequence of operation for the VAV systems is such that a constant difference in CFM, amounting to the outdoor air quantity for the air handling system, shall be maintained between the supply and return air fans at all times. If the supply air fan volume is allowed to drop to a very low value, the corresponding return air volume shall be even lower as the return air fan has to maintain a constant difference in CFM with respect to the supply air volume at all times. Under this condition, the supply (and particularly the return) air fans could fall in an unstable region where the fan operation is not recommended by the equipment manufacturers.
      ii. The supply and return air fans of the VAV systems are generally equipped with variable speed drives. If these drives are allowed to run at very low speeds for a long period of time, the fan motors will tend to overheat and cause damage to the winding insulation.
5. Outside Air Requirements
   a. GENERAL: The outdoor air for ventilation shall be computed in accordance with the latest edition of ASHRAE 62; however, how it is actually supplied to the occupied spaces would depend upon the type of HVAC system. The outdoor air quantity shall be increased, if required, to meet the space exhaust requirements.
6. Exhaust Air Requirements
   a. The following areas shall be fully exhausted outdoors at the rates specified.

Table 2 - 1 Exhaust Air Requirements	
Janitor Closets	10 Air Changes/Hr.
Locker Rooms	10 Air Changes/Hr.

Table 2 - 1 Exhaust Air Requirements	
Mechanical Equipment Rooms:	
Fan Rooms	12 Air Changes/Hr.
Soiled Storage Spaces	6 Air Changes/Hr.
Toilets	10 Air Changes/Hr.

b. Notes:
   i. The ducted supply air shall not be used to ventilate the janitor closets and private toilets with one fixture. Instead, room air from the occupied spaces and corridors, directly connected to the janitor closets and private toilets shall be used as make up air for exhaust.
   ii. The ducted supply air shall be used to ventilate the public toilets equipped with multiple fixtures. The public toilets shall be treated as a dedicated temperature control zone. To maintain 15% negative pressure in public toilets, room air from the corridors shall be transferred as make up by door louvers and/or undercuts.
   iii. The locker room shall receive ducted supply air and shall be treated as a dedicated temperature control unit. All air supplied to the locker rooms (and make up air transferred from the corridors to maintain negative pressure) shall be exhausted outdoors through the toilets/showers adjoining the locker room.
   iv. The soiled storage spaces shall receive ducted supply air and shall be maintained under negative pressure (15%) by drawing room air through the door undercut.

7. Entrances
   a. Use forced air heater at all building entrances.

8. Exterior Stairs
   a. Provide heat in all exterior stairs.

9. Connecting Corridor HVAC
   a. Provide cooling and heating, as approved by EMU, in the connecting corridors between the buildings.

10. Noise Criteria
   a. Occupied Spaces:

Occupied Spaces	
Area	**Maximum NC**
Auditorium, Theaters	35
Offices, Small Private	40
Offices, Large Open	35
Lobbies, Waiting Areas	35

Occupied Spaces	
Area	**Maximum NC**
Corridors	40
Bathrooms, Toilets	40
Laboratories	45
Dining, Food Service/Serving	45
Gymnasiums, Recreation Rooms	50
General Work Rooms	40
All Other Occupied Areas	35 – 40*

*Consultants shall discuss with EMU any specific area requiring NC levels outside this range.

i. Notes:
   1. The above NC levels must be attained in all octave bands.
   2. The above NC levels may be increased for the areas equipped with fan coil units. The designer shall submit an analysis showing the expected noise levels for the prior approval of EMU.
   3. **The systems must be engineered and the use of acoustic sound lining and sound attenuators should be considered to achieve the design sound levels.**

b. Cooling Towers: Select and locate the cooling towers to avoid problems with:
   i. Noise
   ii. Vibrations
   iii. Aesthetics
   iv. Drift
   v. Air Recirculation

11. HVAC Equipment Sizing Criteria
   a. Air Handling Equipment: To compensate for the duct air leakage and any future space internal heat gain, the equipment must be sized in accordance with the following guidelines:
      i. Load Calculations: Heat gain calculations must be done in accordance with the procedure outlined in the latest ASHRAE Handbook of Fundamentals. The calculations performed either manually or with a computer program shall not include any built-in safety factors.
      ii. The calculated supply air shall be the sum of all individual peak room air quantities without any diversity, even for the variable air volume systems.
      iii. Safety Margin: A safety factor of 5 percent shall be applied to the calculated room air quantity to allow for any future increase in the room internal load.
      iv. The adjusted supply air shall be, thus, 5 percent in excess of the calculated supply air.

v. Air leakage: The air leakage through the supply air distribution ductwork shall be computed on the basis of the method described in the SMACNA Air Duct Leakage Test Manual. The maximum leakage amount shall not exceed 4 percent of the adjusted supply air.

vi. Supply Air Fan Capacity: The capacity of the supply air fan shall be calculated per the following example:

1. Calculated Supply Air Volume = 20,000 CFM
2. Safety Margin = 5 percent of item (1)= 1,000 CFM
3. Adjusted Supply Air Volume = 21,000 CFM
4. Duct Air Leakage = 4 percent of item (1)= 840 CFM
5. Supply Air Fan Capacity = 21,840 CFM

vii. Equipment Selection: selection of the supply air fan, cooling coil, preheat coil, energy recovery coil (if any), filters, louvers, dampers, etc., shall be based on the supply fan capacity, 21,840 CFM calculated in the example above. A psychometric chart shall be prepared for each air-handling unit. Make sure heat gains due to the fan motor and duct friction losses are taken into account for sizing cooling coils.

viii. Air Distribution:

1. The main supply air ductwork shall be sized to deliver the supply air fan capacity, 21,840 CFM as calculated in the example above.
2. The individual room air distribution system including supply, return, exhaust air ductwork, air terminal units, reheat coils and air outlets/inlets shall be sized and selected on the basis of the adjusted supply air volume, 21,000 CFM.
3. The fan and motor selection shall be based on the supply air fan capacity and static pressure adjusted, as necessary, for the altitude, temperature, fan inlet and discharge conditions, and the AMCA 201 System Effect Factors. The fan selection shall be made within a stable range of operation at an optimum static efficiency. The fan motor BHP, required at the operating point on the fan curves, shall be increased by 10 percent for drive losses and field conditions to determine the fan motor horsepower. The fan motor shall be selected within the rated nameplate capacity and without relying upon NEMA Standard Service Factor.

12. Chilled Water Systems

a. The capacity of the chilled water system, which consists of condenser and chilled water pumps, cooling tower, piping, etc., shall be based on the sum of the total cooling requirements of all connected air handling units. No additional safety factors should be required.

13. Duct Sizing Criteria
    a. Duct systems should be designed in accordance with the general rules outlined in the latest ASHRAE Guide and Data Books, SMACNA Manuals and Design Guide Section of the Associated Air Balance Council Manual.
    b. Supply duct system, with total external static pressure 2 inches and larger, shall be designed for a maximum duct velocity of 2500 fpm for duct mains and a maximum static pressure of 0.25 inch of water gage per 100 ft. Static pressure loss and regain shall be considered in calculating the duct sizes. Size supply branch ducts for a maximum duct velocity of 1500 fpm.
    c. All other duct systems such as return and exhaust, including branch ducts, shall be designed for a maximum velocity of 1500 fpm for the duct mains and a maximum static pressure of 0.10 inch of water gage per 100 ft, with the minimum duct area of 48 sq in, that is 8 in x 6 in size.
14. Pipe Sizing Criteria
    a. Pipe sizing shall be based on "Cameron Hydraulic Data"; with C=100 for open systems (Example: Cooling Tower) and C=150 for closed systems (Example: Chilled and Hot Water Systems).
    b. For closed systems, the limited maximum pressure drop shall be 4.0 feet of water per 100 feet equivalent length of piping. The corresponding velocity limitations are:
        i. 4.0 Feet Per Second: Occupied Areas
        ii. 8.0 Feet Per Second: Mains and Large Branches
    c. For open systems, the limiting maximum pressure drop shall be 4.0 feet of water per 100 feet equivalent length of piping. The corresponding velocity shall be 10 feet per second (maximum).
    d. **The minimum pipe shall be 3/4".** The size shall be reduced, as required, only at the equipment connections.

Section 23 00 06 Contract Drawings

1. General
    a. Refer to EMU Standard Details and EMU CAD Standards. Sheet notes and general type notes should be listed on the right hand side of the sheet. Lettering on drawings shall be minimum 32 mm (1/8 inch) high.
2. Specific Requirements
    a. The contract drawings shall include those listed below.
        i. General Notes, Abbreviations and Symbols.
        ii. Equipment Schedules. Include schedules for existing air handling units, fans, pumps, etc., that will require alteration or rebalancing.
        iii. Details and other necessary details.
        iv. Flow Diagrams for Air Supply, Return and Exhaust for each HVAC system.
        v. Temperature Control Diagrams and Sequence of Operation for all HVAC Systems, including "Sequence of Operation" written on the drawings alongside the control diagrams.

vi. Flow and Control Diagrams for Chilled Water and Hot Water Systems. Flow diagrams shall show entire system on a single drawing.
vii. Flow and Control Diagrams for Steam and Condensate Piping Systems.
viii. Riser Diagrams for chilled water, hot water, drain, steam and condensate, and supply air, return air and exhaust air systems where applicable. Flow diagrams may eliminate the need for riser diagrams.
ix. Demolition of existing HVAC work, if applicable. Minor demolition may be shown on new construction drawings. Extensive demolition requires drawings for demolition only.
x. Floor Plans 1/8" = 1'-0" for Equipment, Piping and Ductwork.
xi. Floor Plans and Sections 1/4" = 1'-0" for Mechanical Rooms.
xii. Floor Plans 1/4" = 1'-0" for Mechanical Chases at each floor showing ducts, dampers, piping and plumbing.
xiii. Sections shall be shown, as required, to clarify installation, especially thru areas of possible conflict. Show all the equipment including plumbing and electrical.
xiv. Room numbers and names shall be shown on HVAC plans at every review stage including schematic submissions.

3. Heat exchangers, coils, pumps and chillers in glycol-water system shall be identified on the equipment schedule showing the percent glycol by volume of the circulating fluid for equipment de-rating purposes.
4. Piping Drawings
    a. Avoid piping routing through rooms containing electrical or communication equipment.
    b. Branch piping serving each floor shall have shut-off valves at mains to isolate branch.
    c. Show sections or profiles of underground piping to show elevation with respect to grade, roads and possible conflicting utilities, including provision for draining and venting.
5. Ductwork Drawings
    a. All ductwork 18-inches in width and larger shall be shown double line.
    b. Manual air volume balancing devices shall be provided in supply return and exhaust mains, branch mains and terminal branches. Ceiling access panels are to be installed, where required, for access to balancing devices. Location of balancing devices shall be shown on the contract drawings.
    c. Dampers in room diffusers and registers shall be used only for minor balancing requiring a maximum pressure drop of approximately 0.10 inch of water gage. Registers and/or diffusers shall not be located on main ducts or main branches. They shall be located on individual branch ducts with opposed blade balancing dampers in the branch to reduce room noise transmission.

d. Air quantities on plans shall be "rounded off" to the nearest increment of 10 CFM.

6. Equipment Schedules
   a. Equipment Schedules shall be listed in the following order, vertically, from left to right, to facilitate checking and future reference. Trade names or manufacturer's model numbers shall not be shown.
      i. Air Conditioning Design Data (Outdoor design and indoor design conditions for the various occupancies)
      ii. Air Flow Control Valves
      iii. Air Flow Measuring Devices
      iv. Air Handling Equipment
      v. Air Separators
      vi. Chillers, Condensing Units, Air Cooled Condensers
      vii. Convertors
      viii. Cooling Towers
      ix. Building Automation System (BAS)
      x. Expansion Tanks
      xi. Fans
      xii. Fan Coil Units, Air Terminal Units (Boxes)
      xiii. Filters for closed loop Water Systems (chilled water and hot water)
      xiv. Finned Tube Radiation
      xv. Heat Recovery Equipment
      xvi. Humidifiers
      xvii. Pre-filter, after-filter (may be combined with pre-filters)
      xviii. Preheat Coils, Cooling Coils, Reheat Coils
      xix. Pressure Reducing Valves, Safety Valves
      xx. Pumps
      xxi. Radiant Panels
      xxii. Room By Room Air Balance
      xxiii. Sound Attenuators
      xxiv. Supply, Return and Exhaust Air Diffusers and Registers
      xxv. Unit Heaters
      xxvi. Vibration Isolators
      xxvii. Water Flow Measuring Devices
      xxviii. Other Schedules As Required
   b. Equipment performance and capacity data shall correspond to that shown in the calculations, not a particular manufacturer's catalog data, but the data shall be in the range of available manufactured products.
   c. Convertors, coils, pumps and chillers in glycol water system shall be identified on the equipment schedule showing the percent glycol by volume of the circulating fluid for equipment de-rating purposes.

Section 23 00 07 HVAC Calculations and Analyses

1. Calculations shall include room by room heat gain and loss; room by room air balance showing supply, return, exhaust, transfer, and make-up air quantities; equipment capacities; economic analysis; and sound and vibration analysis. Calculations and analysis should be identified, arranged and summarized in proper format. They shall be indexed in a bound folder with each air handling unit as a zone and separate chapters for cooling loads, heating loads, exhaust systems, pumping/piping calculations, fan selections, etc.
2. Heat transfer coefficients, solar radiation, psychometrics, duct and pipe sizing, etc., and calculations and analysis shall be in accordance with the ASHRAE Handbooks and EMU Design Criteria.
3. Fan and pump motor horsepower, reheat, and duct heat gains shall be included in cooling load calculations.
4. In addition to internal loads for people and lights include heat gain from equipment, such as sterilizers, washers, burners, ovens, refrigerators and dietetic.
5. The use of computer programs and calculations is acceptable and desirable. Calculations should, however, be keyed to appropriate room, zone, and unit numbers for each identification.
6. Economic analysis concerning cost of steam generation shall be based upon fuel cost and boiler plant efficiency as provided by the EMU Physical Plant. Analysis should include an assessment of future availability of fuels, particularly natural gas.
7. Economic analysis concerning electrical energy cost should be calculated based upon input from the EMU Physical Plant.
8. Review Submittals
    a. In addition to calculations and drawings, the submission shall include copies of the equipment selection engineering data (handwritten worksheets), by unit number, including the following:
        i. Air handling unit capacity and sketch of component arrangement with physical dimensions for louvers, dampers, access provisions, filters, coils, fans, vibration isolators, etc.
        ii. Required performance (Pressures, flow rate, horsepower, motor size, etc.) for all air handling units, fans and pumps for intended modes of operation. Include fan and pump performance curves.
        iii. Coil selections for preheat, heating, cooling and energy reclaim.
        iv. Heat recovery equipment.
        v. Refrigeration equipment loading, performance and selection.
        vi. Cooling tower performance, winterization (heaters) and noise analysis.
        vii. Sound attenuation for fans, ductwork and terminals.
        viii. Steam PRVs, by-passes and safety valves.
        ix. Typical catalog cuts of major equipment.

Section 23 00 08 Equipment Location and Installation

1. General
   a. Equipment shall be located to be accessible for installation, operation and repair. Mechanical spaces shall be of suitable size to permit inspection and access for maintenance, and to provide space for future equipment when required. The effect that equipment noise or vibration might have on areas adjacent to, above, and below equipment shall be considered. Location of equipment remote from sound sensitive areas should be emphasized. Design shall comply with specified room sound ratings.
2. HVAC Equipment
   a. Air handling units and similar equipment shall be housed in a mechanical equipment room or in a mechanical penthouse building. Penthouse type of fully weatherized roof top units constructed in standard sections of modules would be acceptable in lieu of the mechanical equipment rooms or mechanical penthouses. These units shall provide excess sections for walk through servicing, maintenance, and shall ensure that the piping connections and electrical conduits are fully enclosed within the units. The designer shall ensure close coordination with the architecture and structural disciplines for aesthetics, operating weight, shaft locations, etc., while selecting the roof top units.
3. Coordination
   a. Coordinate and make provisions for all necessary stairs, cat walks, platforms, steps over roof mounted piping and ducts, etc., that will be required for access, operation and maintenance. Access to roofs by portable ladder is not acceptable.
4. Cooling Towers
   a. Select and locate cooling towers to avoid problems with aesthetics, noise, vibrations, air recirculation or drift. Include a noise analysis of the proposed cooling tower relative to adjacent occupancies and consider alternative cooling tower selections, if necessary, to meet noise level of 60 dB(A) at 50 feet which may be lowered for critical locations. Consider provisions for security and maintenance lights and receptacles. Provide a permanent service platform and ladders for access to cooling tower basin access doors.
5. Air Compressors
   a. Large control air compressors can be a source of objectionable noise and vibration. They should be mounted on vibration isolators and should be located to avoid noise problems in occupied areas, including shops and the engineering control center. Compressors may require an enclosure or acoustical treatment.

6. Screens and Filters for Air
   a. Areas where cottonwood trees, or similar types, are likely to interfere with operation of air intakes for air handling units, cooling towers, or air cooled condensers, provide easily cleanable screens or roughing filters at the air inlets.

Section 23 00 09 Locations of Outside Air Intakes and Exhaust Air Outlets

1. General
   a. Outside air intake and exhaust air outlets shall be located to avoid health hazards, nuisance odors and reduction in capacity of air conditioning equipment and corrosion of equipment caused by re-entry of exhaust air from laboratories, transportation systems, cooling towers and air cooled condensers, etc.
2. Minimum Requirements
   a. The bottom of all outdoor intakes shall be located as high as practical but not less than three feet above ground level or, if installed through the roof, one meter (three feet) above the roof level.
   b. Laboratory and Research exhaust shall be terminated at the highest point of the building (NFPA 99, 5-3.3.4).
   c. Outside air intake shall not be near hot exhaust discharging horizontally or deflected down, nor be near plumbing vents, animal room exhausts, generator exhausts, loading docks, automobile entrances, driveways, passenger drop-offs, cooling towers, incinerator and boiler stacks.
3. Special Requirements
   a. Separating air intakes and exhaust air outlets by 10 m (30 ft) as recommended by codes is a minimum requirement under ideal conditions. Other factors such as wind direction, wind velocity, stack effect, system sizes, and height of building must be evaluated and location of intakes and outlets shall be adjusted as required. Refer to Chapter "Air Flow around Buildings" of ASHRAE Fundamentals Handbook for analyzing these factors.

Section 23 00 10 Design for Existing Buildings

1. General
   a. The designer is responsible for surveying the existing buildings to determine if adequate space is available for ducts and equipment. He must not rely upon the furnished record drawings alone. Early in the design stage, arrangements must be made with the Physical Plant Engineering Managers for access above ceilings to determine field conditions and to locate existing HVAC including steam lines and other services. Consider that most corridor ceiling spaces are loaded with equipment to remain and may create installation problems for new equipment. Provide sections to resolve conflicts. Required demolition of existing HVAC work must be shown on the drawings. Location of new equipment and services must be coordinated with all involved parties.

Phasing of the construction work must be coordinated with operation of the facility and EMU staff and be provided for in the design.

b. In existing buildings, the floor-to-floor heights are generally less than 3.6 m (12 feet). In addition, the building structure elements also occupy substantial spaces between the underside of the slab and the suspended ceilings. The installation of an all air system is therefore very difficult, if not impossible. During the schematic stage, the A/E shall make a detailed evaluation of the available space and determine whether the installation of an all air system is feasible. If all air systems are not feasible, the need to perform a life cycle cost analysis shall be reviewed with the EMU project manager.

c. If EMU wishes to retain the existing HVAC equipment, considered obsolete as a result of modification, this should be noted on the demolition drawings; otherwise, the contractor in accordance with the General Conditions of the contract will dispose it off.

d. Investigate the conditions of the existing steam supply and condensate return piping and provide recommendations.

2. HVAC System Upgrade

a. Unless directed, or approved otherwise by EMU, the existing steam radiators or convectors heating systems shall be dismantled and hydronic hot water heating system shall be provided when air conditioning systems with mechanical cooling are added to an existing building.

b. If the existing radiators or convectors are to remain in place, the scope of work, at a minimum, shall include installation of new modulating control valves in the steam supply lines and installation of new float and thermostatic steam straps in the steam condensate return lines. In addition to that, the room temperature control sequence shall be arranged in such a manner that a single room thermostat shall control cooling and heating, in sequence, to avoid any possibility of mechanical cooling and steam heating to be in operation together. The installation of the new steam control valves and new steam traps involve considerable expense for retrofitting and existing steam terminal heating devices. This expense should be carefully weighed before deciding against hydronic hot water heating systems.

c. If the existing steam heating systems are equipped with any zone control arrangement, the same should be disconnected in place so that the zone controls do not create any operating conflict with the room temperature controls proposed above.

Section 23 00 11 HVAC Systems and Equipment

1. HVAC Systems Selection Requirements

a. General

i. The HVAC System for a specific project shall be selected through an engineering economic analysis to ensure that the system is cost effective.

b. Existing Buildings
   i. Where an all-air system cannot be used due to physical limitations, EMU may waive the requirement for a life cycle cost analysis.

2. Special Requirements for All Air Systems
   a. Variable Air Volume (VAV) Systems
      i. As far as possible, VAV systems shall be used with all air systems, except for spaces requiring constant air changes/hours, and/or critical pressure differentials with respect to the adjoining spaces.
   b. Interior Rooms
      i. Only all-air systems shall be used for interior space to take advantage of free cooling by an economizer cycle. When the existing exterior rooms become interior rooms because of new construction or modifications, the HVAC system for these rooms must be checked and modified to all air systems provided these rooms are not already served by all air systems. This is required even though these rooms may not be a part of the new or modification project.
   c. Terminal Reheat System
      i. Use of constant volume with terminal reheat systems shall be confined to areas such as laboratories, and animal research rooms.
   d. Return Air Fans
      i. All air-handling units using return air shall be furnished with return air fans for economizer cycle capability, pressure relationship, and to facilitate positive control of air balance.
   e. System Zoning Requirements
      i. General Guidelines: EMU criteria for zoning HVAC systems and the selection of the type of air handling units (AHUs) is based on the specific HVAC requirements of the departments, life cycle cost analysis, and energy conservation. For existing facilities, considerations listed below could also influence the selection of HVAC systems.
         1. Space availability for equipment, piping, and ductwork
         2. Phasing requirements
         3. Capacities and conditions of the existing HVAC systems, if any, serving the areas to be renovated
         4. Impact of the renovation activities on the adjoining areas not included in the project
      ii. It is generally desirable to follow the structural and architectural symmetry of the building by providing a dedicated AHU to service a specific module/quadrant. This approach should not compromise the functional integrity of the spaces. Deviations from providing dedicated AHUs should be referred to EMU with specific information as to the extent and impact of any violations.

f. Exhaust Requirements
   i. Exhaust air shall be ducted for all spaces, i.e., air shall not be taken through mechanical equipment rooms, corridors or furred spaces. Circulation of air directly between functional areas is not permitted, except for toilet rooms and janitor closets. The exhaust air to the toilet should be transferred via door undercuts or louvers. Transfer grilles are not permitted between corridor and occupied spaces.

3. HVAC Equipment Requirements
   a. Air Handling Units
      i. EMU preference for air-handling units is for the draw-thru type.
      ii. The blow-thru type air handling units shall generally not be used because the fully saturated air leaving the cooling coil could cause water damage to the after-filters and sound attenuators, located on the downstream side of the cooling coils. Exception: For any specific situation, if the use of the blow-thru type air-handling unit is deemed necessary, locate the after-filters on the upstream side of the supply air fans. And the duct-mounted sound attenuators shall be located as far away as possible in the supply air ducts, preferably on the downstream side of the air terminal units. A factory fabricated diffuser section shall be installed on the downstream side of the supply air fan to ensure uniform distribution of the air velocity over the face of the cooling coil. Such a deviation should, however, be reviewed with and approved by EMU before incorporating it into the design documents.
      iii. All air-handling units comprised of coils, fans, filters, etc. shall be of double wall construction**.** These units shall be factory-fabricated and field-assembled. The larger units could, however, be field-assembled.
      iv. Show access sections and door swings on contract drawings**.** The air handling unit air pressure shall act to seal the access doors.
      v. Fans: Airfoil (AF) or backward inclined blade fan wheels are preferred. However, EMU does allow forward curved blade wheels with certain provisions. The variable speed motor controller may be used for smaller systems only if it is cost effective, saving 50 percent of the energy compared to the constant volume system. Evaluation of this requirement shall consider hours of operation (24 hours versus 10 hours) and part-load conditions. The variable inlet guide vanes shall not be used for fan volumetric control.
      vi. Coils
         1. Cooling coil velocity shall not exceed 500 fpm for constant volume systems and 550 fpm for variable air volume systems. Intermediate drain trough shall be provided for each coil bank more than one coil high. The external drain of each air handling unit coil section shall have a deep seal trap and be extended to an open sight

drain. Deep-seal traps will necessitate raising of coil section and most likely the entire unit above the floor or disposing of drainage on the floor below.

2. Preheat coils shall generally be steam type. If a steam preheat coil is used, the designer shall evaluate the impact of numerous parameters, such as air temperature entering the preheat coil, steam pressure, modulating or on/off steam control valve, coil length, etc. This will ensure uniform heat transfer over the coil surface and prevent stratification of air, which could result in actual freeze-up conditions or false tripping/alarms of the freezestats. Further, if a steam coil is used for 100 percent outdoor air handling units, it shall be equipped with integral face and by-pass damper and two-position steam control valve.
3. Heating/Reheat Coils: The unit mounted heating coils shall preferably be hot water type. The face velocity of these coils shall not exceed 550 fpm.
4. Coil Sizing: When heat recovery equipment is used, the pre-heat/heating coil and chilled water coil shall be designed to function at full load with, and without, energy recovery. All coil schedules shall show both entering air conditions.
5. Piping: Piping to coils shall be offset and shall have shut-off valves and flanges or unions to permit removal of the coil from the side of the air handling unit.

b. Air Filters

i. Generally, pre-filters and after-filters shall be located on the upstream side of the supply air fan in the same frame. IF space limitations or other reasons require the after-filters to be located on the downstream of the supply air fans then a factory fabricated diffuser section shall be installed between the fan and the filters to ensure uniform distribution of air velocity over the face of the after-filters.

ii. Filters Efficiencies:

1. Efficiencies shall comply with test method specified by ASHRAE standard 52.1.
2. Filters for room fan coil units and packaged air conditioners shall be manufacturer’s standard.
3. Filters for the central ventilation air handling units providing minimum outdoor air for fan coil systems or radiant ceiling panel systems, shall be equipped with 2 inch thick throw-away pre-filters of 15 percent efficiency and after filters of 60 percent efficiency.

4. Filters for the central air handling units serving examination and treatment rooms, etc., shall be equipped with pre-filters of 30 percent efficiency and after-filters of 85 percent efficiency. For critical areas, the after-filter efficiency would be as high as 95 percent efficiency.
5. Following Table lists filters efficiency for various areas:

Filter Efficiencies (percent) for all Air systems

Area Served	Pre-filters (Efficiency)	After-filters (Efficiency)
Animal Holding Areas	30	85
Animal Operating Rooms	30	95
Administrative areas, conference rooms, and lobbies	15	60
Auditoriums and Theaters	15	60
Dietetics (Kitchen and Dining areas)	15	60
Gymnasium	15	60
Heat recovery Units (In exhaust air on upstream side of the coil)	30	-
Laboratories, supply system	30	85
Warehouse	30	-

a. Notes:
   i. 2 inch thick throw-away filters with 15 percent efficiency are not rated or tested as per ASHRAE standard 52.1.
   ii. Design face velocity should not exceed 500 FPM for all filters. Preferred filter dimensions are 24 inch x 24 inch. Return and outdoor air (mixed air) shall pass through pre-filters and after-filters.

c. Central Humidifiers
   i. Central humidifiers shall be steam manifold jacketed type with duct mounted sensor/controller and high limit control. To protect the after-filter from moisture, the humidifier shall be installed downstream of the after-filter.
   ii. The A/E shall consider use of chemically untreated steam source that does not require use of facility's boiler steam, and make recommendations to EMU before proceeding with design.

d. Duct Lining and Sound Attenuators
   i. Field applied duct lining is not permitted in the supply air ducts. Omission of duct lining usually requires sound attenuators in the ductwork to meet the specified NC criteria. Perform sound analysis to ascertain the need for sound attenuators.

ii. Air Terminal Units: Factory applied fiberglass liner, with coating to prevent erosion and no exposed edges, is permitted in air terminal units located downstream of the after-filters.

e. HVAC Drains
   i. General
      1. All condensate from air conditioning equipment and other HVAC drains, including cooling tower overflow and floor drains, shall discharge into the sanitary sewer system.
      2. Drains from air conditioning equipment shall terminate, with an air gap, above the flood level rim of plumbing fixtures, such as floor drain, floor sink, sink, or open sight drain. Direct connection to the plumbing system shall not be permitted.
      3. Open-sight drains are not permitted in concealed spaces.
   ii. Fan Coil Units, Run-around Heat Recovery Coils and Computer Room A/C Units shall have condensate drain lines, even if designed for sensible cooling only.
   iii. Specific Requirements
      1. Avoid condensate drains discharging through outdoor walls, unless specifically approved by EMU.
      2. Minimum horizontal drain pipe shall be 3/4-inch.
      3. Maximum horizontal run shall be 40 feet. Provide cleanouts in drain piping.
      4. Provide a sufficient number of unit drain risers to permit a slope in the horizontal drain lines of at least one inch per 40 feet.
      5. Deep seal traps are required on air handling units. Proper installation of these traps will typically require raising the air handling unit or locating the traps below the floor level.

4. Variable Air Volume (VAV) Systems
   a. General
      i. VAV systems shall be single duct with, preferably hot water, terminal reheat coils or dual duct type.
      ii. All exterior and interior patient care areas, such as treatment and examination rooms shall have reheat coils in the air terminal units.
      iii. Pressure-independent terminal units with factory set, but field adjustable, maximum and minimum air volumes settings are required.
   b. Special Considerations
      i. For all occupied patient spaces, exterior and interior, the minimum setting of air terminal units shall be such that the minimum ventilation needs of the occupants are met at all times. Provide reheat coils for the terminal units serving the perimeter spaces.

ii. The volumetric control for the supply and return air fans shall be accomplished by the airflow measuring devices and the variable frequency drives. The sequence of operation shall be such that the constant difference in air quantity shall be maintained between the supply and return airflows from full load to part load conditions.

5. Room Fan-Coil Units
   a. General
      i. Use of fan coil units for cooling in new construction areas is not permitted due to humidity and condensation concerns. However, in existing buildings with physical limitations such as inadequate furred ceiling and shaft spaces and mechanical rooms for equipment and ductwork use of fan coil units is permitted.
      ii. Floor mounted, vertical, four-pipe fan coil units (located under the windows) shall be used for perimeter offices, and other exterior spaces requiring mechanical cooling, provided the system is proved to be cost effective on the basis of a life cycle cost analysis when compared with other HVAC systems. The minimum outdoor air for this system shall be directly distributed to the spaces from central air handling unit(s) via ductwork and air outlets. The outdoor air shall either be exhausted through bathrooms and toilet rooms or directly from the spaces.
   b. Installation Restriction
      i. Ceiling-mounted (above or below the suspended ceiling) fan coil units are not permitted, unless there are physical limitations in an existing building where it is not possible to install them under the windows.
   c. Interior Rooms
      i. Fan-coil units shall not be used in interior rooms where chilled water may not be available to handle the cooling load in cold weather.
6. Radiant Cooling Panel Systems:
   a. Radiant cooling panel systems are not permitted.
7. Heating Systems
   a. General: This section includes requirements for all heating systems using the following mediums:
      i. Hydronic Heat (Hot Water or Hot Glycol Water solution)
      ii. Steam
      iii. Electricity
      iv. Natural Gas or Liquid Propane Gas (LPG)
   b. Perimeter Heating
      i. Perimeter heating system(s) shall be provided for all occupied exterior areas. Other exterior areas should be reviewed with EMU to determine if perimeter heating will be needed.

c. Hydronic Heating
  i. General
    1. Hot water heating system is preferred where extensive runs of piping with multiple terminal units, such as air terminal units (Variable Air Volume or Constant Volume Boxes) and/or perimeter heating devices, are involved.
    2. The minimum pipe size shall be 3/4 inch.
  ii. Equipment
    1. Unit Heaters and Cabinet Unit Heaters
    2. Finned Tube Radiation
    3. Convectors
    4. Radiant Heating Ceiling Panels
    5. Heating Coils mounted in air handling units and terminal units, such as fan coil units and VAV/CV boxes
    6. Air Curtains
  iii. System Configuration: The heating hot water shall be produced by steam to hot water heat exchanger.
    1. System Capacity
      a. For any hydronic heating system with pumping capacity equal to or smaller than 5.0 HP, provide two heat exchangers and circulating pumps of 100 percent capacity each. One heat exchanger and pump shall act as stand-by.
      b. For any hydronic system with pumping capacity larger than 5.0 HP, provide two heat exchangers and circulating pumps of 50 percent capacity each. No stand-by equipment is required.
    2. For reheat and miscellaneous heating applications, such as duct-mounted hot water coils, fan coil units, unit heaters, radiant panels, cabinet unit heaters, heat exchangers, etc., provide one common heating system comprising of two heat exchangers, two circulating pumps, and associated piping. The use of two totally separate and independent heating systems (one for reheat and other for perimeter terminal units) shall be considered only if the use of two systems is proven to be cost effective by the life cycle cost analysis. With a single common heating system care shall be taken to select the lowest hot water temperature and optimum flow rates to compensate for the effect of the hot water temperature reset schedule and to offset the generally constant reheat load of the interior spaces.

3. When the heating hot water system is selected for the preheat application, where ambient or mixed air is below freezing, the hot water shall be mixed with glycol to prevent freezing of the coil. This system shall be independent of heating/reheating and shall be designed with two heat exchangers and two pumps.
4. For heating hot water systems with pumping capacities of 7.5 HP and smaller and with tight space conditions, use in-line centrifugal pumps. For all other systems, use floor mounted, open drive centrifugal pumps. The pump speed, in either case, shall not exceed 1750 RPM.
5. Provide a by-pass type cartridge water filter, 1 to 2 percent of total flow capacity.

iv. Controls

1. Provide a hot water temperature reset schedule to be inversely proportional to the outdoor air temperature. The heating hot water or glycol solution temperature shall not be less than 140 degrees F. The reset schedule shall be adjustable.
2. For a system involving multiple terminal units, the use of variable flow heating system with two-way, straight thru, modulating valves is strongly preferred over a constant flow system involving 3-way, modulating, bypass valves. On systems using two-way valves, care shall be taken to prevent "dead heading" of pumps or no flow conditions by:
   a. Providing at least 15 percent constant flow. This can be achieved by providing three-way, constant flow valves at the farthest end of each circuit.
   b. Constant fixed by-pass at the farthest end of each circuit. An automatic by-pass arrangement based on the pressure differential control may be needed to limit the variable flow operation with pumps "riding the curves".
3. For large applications, the use of primary-secondary pumping with variable speed pump control should be evaluated.

d. Steam Heating

i. General

1. Do not use floor-mounted steam radiators for spaces without sub-basements, pipe basements, or crawl spaces to avoid problems with steam condensate return.

ii. Applications
   1. The use of steam shall also be considered for:
      a. Air Handling Units: To preheat the mixed air up to 55 to 60 degrees F, that is, to match with the cooling coil leaving air temperature.
      b. Heating and Ventilation Units: To heat the outdoor air as determined either by room thermostat or a discharge air temperature sensor.
   2. Extensive use of the duct mounted steam reheat/heating coils shall be avoided to alleviate the problems of
      a. Steam Condensate Return
      b. Lack of space available above the suspended ceiling for installation of steam traps, 12 inches minimum, and for dirt leg additional 6 inches.
      c. Trap Maintenance
      d. Objectionable noise due to steam whistling, condensate flow, and water hammering

iii. Equipment
   1. Unit Heaters, Heat Exchangers, and Radiators
   2. Air Handling Units
   3. Heating & Ventilation Units

iv. Controls**:** The steam heating equipment shall be thermostatically controlled. Wherever the steam heating equipment is used in a space, cooled by the mechanical refrigeration, a single thermostat, to avoid the possible occurrence of simultaneous cooling and heating, shall control the space temperature.

e. Electric Heating
   i. General: The electric resistance heating is expensive and its use shall be considered only if the heat generated by the fossil fuels is not available.
   ii. Application: The electric heating should be considered for:
      1. Emergency Generator Rooms
      2. Elevator Machine Rooms
      3. Electrical Switchgear Rooms
   iii. Equipment
      1. Unit Heaters & Cabinet Unit Heaters
      2. Convectors
      3. Radiant Heating Ceiling Panels
      4. Baseboard Radiation
      5. Air Curtains
      6. Unit Mounted Heating Coils
      7. Air Terminal Units

iv. Controls: The electric heat shall be thermostatically controlled. Wherever the electric heating equipment is used in a space, cooled by the mechanical refrigeration, a single thermostat, to avoid the possible occurrence of simultaneous cooling and heating, shall control the space temperature.

f. Gas Heating:

i. Equipment: The use of the gas heating shall be considered with the following equipment:

1. Unit Heaters
2. Heating & Ventilation Units
3. Roof Top, Self-contained HVAC Units

ii. Controls: The heating equipment shall be thermostatically controlled to maintain the design temperatures.

g. Pressure Reducing Valves (PRV) and PRV Stations

i. Size PRV stations for calculated peak demand of building heating, domestic hot water, humidification, and equipment (process) load. For equipment load, use 100 percent steam consumption of the largest single user plus 25 percent steam consumption of all other users.

ii. Where a single PRV would exceed 4-inch size or the turn-down ratio (maximum load/minimum load) is greater than 10, provide two PRVs in parallel, approximately 1/3 plus 2/3 with a single by-pass. Where the steam service includes capacity for future expansion, size all PRV station components for the future capacity. Size the PRVs for the present load only. Show globe valves to by-pass the main shut-off valves.

iii. Size the PRV by-pass valve and the safety valve according to National Board Inspection Code of the National Board of Boiler and Pressure Vessel Inspectors. Size the safety valve to handle the maximum flow of the largest PRV or the by-pass. Verify that the by-pass valve capacity does not exceed the capacity of the safety valve.

iv. Mechanical Equipment Rooms: The rooms in which PRV stations, pumps, converters, heat exchangers, etc., are located, shall be of suitable size to permit easy access for maintenance. If duplex condensate pump is installed in a pit, the starter, disconnect switch, and alternator are to be located outside the pump pit.

h. Steam Piping

i. Size steam piping according to ASHRAE Guide and Data Books.

ii. Design steam and condensate piping with loops, bends and offsets to allow for thermal expansion and keep stresses within the allowable limits of the piping material. Avoid using expansion joints or ball joints, if possible.

iii. Provide roller-type pipe supports where significant horizontal pipe movement will occur due to thermal expansion and spring-type supports where significant vertical movement will occur.

iv. The minimum pipe size shall be 1-inch in horizontal runs and 3/4-inch in vertical runs; make any pipe size reduction necessary at the equipment. Long horizontal pipelines shall not be run at the floor. Wherever possible, provide up feed connections through the floor to the equipment.

v. For large steam service, such as the low pressure system for absorbers, provide small globe type warm-up valve, located for convenient operation, to by-pass the main shut-off valve. By-pass valves shall be shown and specified for gate valves 4 inches and larger in steam lines.

i. Steam Traps

i. Steam traps on domestic hot water heaters, heating coils and other steam equipment utilizing modulating control valves shall be closed float-thermostatic type with operating pressure range suitable for the maximum steam supply pressure. Trap capacities shall be calculated and shown on the drawings in pounds per hour at one-quarter psig pressure differential across the trap provided the inlet of the traps are 12 inches below the condensate outlet of the equipment. The allowable pressure drop across the trap may be increased if the trap leg is allowed to increase. Steam traps shall be sized based on the maximum condensing rate of the equipment they serve times a safety factor of 1-1/2 or 2. Consult the manufacturers of steam traps.

ii. Steam traps on steam line drip points shall be inverted bucket type, with bi-metallic thermal element for air removal, with working pressure range suitable for the maximum line pressure. Trap capacities shall be shown on the drawings in pounds per hour at a specified pressure differential across the trap as follows:

1. For steam lines that will be in operation continuously, with infrequent shut downs, drip traps shall be sized for the line radiation loss, in pounds per hour, times three. The trap pressure differential shall be about 80 percent of the line operating pressure.
2. For steam lines subjected to frequent warm-up, the trap capacity shall be the amount of steam condensed when the line is warmed up to operating condition from a cold condition within a period of ten minutes. The trap pressure differential shall be 1/4 psig.

iii. Steam traps shall be readily available for ease of maintenance.

j. Steam Condensate Piping
   i. Condensate from all pieces of steam operated equipment shall be designed to flow by gravity to return to main, flash tank, or condensate pump set. This condition may require trenches in basement floors when pipe space is not provided below basements. Domestic hot water heaters, heat exchangers, and air heating coils shall be mounted high enough to allow gravity condensate flow by gravity. Where sufficient room height is available, provide a mezzanine or platform for easy access to equipment.
   ii. All condensate shall be returned to the boiler plant by a duplex condensate pump set.
   iii. Use flash tank ahead of condensate pumps on condensate return system from high and medium pressure steam traps. This is to reduce condensate temperature to 200 degrees F and to avoid flashing of hot condensate.
k. Vent Lines
   i. Provide an atmospheric vent line of sufficient size and extend it above the roof of the building. Vents from condensate pump and flash tank shall connect to this vent line. Safety valve shall be extended above the roof, to a height of six feet, independent of the other vent line. To avoid long safety valve discharge piping, safety valves may be located close to the terminal point if there is no shut-off valve between the PRV and the safety valve.

8. Elevator Machine Rooms
   a. General
      i. Following design conditions must be maintained in the machine rooms for safe operation of elevators.
         1. Summer: 94 degrees F or lower
         2. Winter: 50 degrees F
   b. Design Considerations
      i. Provide a dedicated, thermostatically controlled, mechanical ventilation or recirculatory mechanical cooling system to maintain the indoor design conditions. The summer and winter indoor temperatures settings shall be such that simultaneous heating and cooling shall be avoided at any given time. For a specific application, should it become necessary to maintain lower space temperature and humidity for the microprocessor based electronic controls, provide a dedicated cooling unit (DX or chilled water). Heating may be provided by 4-pipe fan coil units along w/cooling or separately by unit heaters.

c. Code Compliance
   i. Mechanical equipment installations in elevator machine rooms shall conform to the National Electric Code. It conforms to rule 102.2 of American National Standard Safety Code for Elevators ANSI/ASME A17.1, which says, "Pipes or ducts conveying gases, vapors, or liquids, not used in connection with the operation of the elevator, shall not be installed in hoistway, or machine room."
      1. Exceptions:
         a. Steam and hot water pipes may be installed in hoistways or machine rooms for the purpose of heating these areas only.
            i. Heating pipes shall convey only low pressure steam 5 PSIG pressure or less or hot water at 212 degrees F or less.
            ii. All risers and return pipes shall be located outside the hoistway.
            iii. Traps and shut-off valves shall be provided in accessible locations outside the hoistway.
         b. Ducts for heating, cooling, and ventilating may be installed in the machine room.
   ii. Life Safety Code NFPA 101 requires that when stand-by power is connected to the elevator, the machine room ventilation or air-conditioning shall also be connected to stand-by power.

d. Heat Emission
   i. Heat emission data for the elevator equipment in the machine room shall be obtained from an elevator manufacturer. Heat emitted includes that from the elevator hoisting motors, motor-generator sets, machine brake coils and all elevator control equipment located in the machine room(s).

9. Emergency Generator Room
   a. General
      i. Indoor Design Conditions:
         1. Summer: 110 degrees F
         2. Winter: 40 degrees F
   b. Provide heat and ventilation in emergency generator building or room when the engine-generator set is idle and operating as well. Analyze noise levels and provide attenuation, if necessary. Electric unit heater, thermostatically controlled shall maintain 60 degrees F minimum space temperature when the generator is not in operation. Extra care should be taken in sizing the unit heater capacity particularly when the radiator and fan are installed in the generator room. The cracks in the exterior walls, which could be caused due to the installation of large louvers and the louvers not fully shut in closed position, could create heavy infiltration of cold air.

c. Engine-Generator Off
    i. Provide a thermostatically controlled ventilation exhaust fan to deliver 15 air changes per hour.
d. Engine-Generator Operating
    i. The air intakes and exhaust outlets shall be located so air does not short circuit and air shall pass over the engine-generator set before it is exhausted. Additional ventilation shall be provided as required to reject the heat from the engine-generator set, muffler (if installed in room) and exhaust pipe.
e. Radiator and Fan Together
    i. When the radiator and fan for the engine-generator are installed in the same room as the engine-generator, provide the following:
        1. A sheet metal plenum, with a flexible connection, between radiator and exhaust louvers.
        2. Two opposed blade power operated dampers, one (normally open) located at the exhaust louver and one (normally closed) located in the sheet metal plenum wall to heat room with waste heat when engine is running. A room thermostat shall modulate the two dampers to maintain a minimum room temperature of 60 degrees F.
        3. Supply air intake shall be large enough to provide make-up air for the radiator exhaust, and the room ventilation. The intake shall have a normally open motor operated damper. Damper shall open whenever the generator or room ventilation fan is energized.
        4. Size the exhaust fan so the combined static pressure loss through the intake and exhaust louvers, and motor operated dampers does not exceed 0.25 inch of water.
f. Radiator and Fan Remote
    i. When the radiator and fan are installed remote to the engine-generator, do the following:
        1. Provide two exhaust fans to ensure the following:
            a. Room Ventilation: The room ventilation fan (capacity: 15 Air Changes/hr.) shall operate either manually or thermostatically when the space temperature exceeds 85 degrees F.
            b. An additional exhaust fan shall operate only when the emergency generator is running and the space temperature exceeds 85 degrees F
        2. Supply air intake shall be large enough to provide make-up air for the two exhaust fans and the combustion air. The intake shall have a normally open motor operated damper and shall open whenever generator or either exhaust fan is energized.

3. Louvers shall have drainable type blades and shall be furnished under architectural specifications. Louvers shall be sized to provide the required air for the two exhaust fans.

g. Transformer Rooms and Vaults

i. General

1. Maximum indoor temperatures of 104 degrees F shall be maintained in transformer rooms (Vaults) and electrical closets with dry type transformers. Small electrical closets without any heat producing devices, such as, dry type transformers, need not be cooled or ventilated. Any pipe or duct system foreign to the electrical installation shall not pass through an electrical room or a closet.

ii. HVAC Systems

1. To prevent excessive heat buildup in transformer rooms, provide a dedicated, thermostatically controlled, mechanical ventilation or cooling system. The requirement of a dedicated system can be waived if the room is served by a building HVAC system that operates 24 hours a day. Design the ventilation system to maintain the space temperature using the outdoor summer design temperature 1 percent value listed in the ASHRAE Weather Data.

h. Exhaust Systems

i. General Exhaust Systems

1. The exhaust systems shall be conventional, low pressure, low velocity type serving toilets, janitor closets, etc. The exhaust systems shall also include areas, with 100 percent exhaust of the supply air, such as laboratories (less special fume hoods), kitchen (less range hood), and animal research (less special fume hoods).

2. In general, each supply air system shall have a corresponding general exhaust system to comply with outdoor air requirements. The exhaust system may or may not be interlocked with supply air system. It shall shut down when supply air system shuts down during unoccupied hours to conserve energy, except exhaust fans shall continue to run when smoke is detected in the areas served by these fans.

10. Refrigeration Systems for Air Conditioning
    a. General
        i. System Types: The refrigeration systems shall be either chilled water or direct expansion (DX) type.
            1. Chilled Water System: Chilled water systems generally use air-cooled or water-cooled chillers or absorption types. Absorption chillers could also be used, if it saves energy. Electric chillers come with a variety of compressors – centrifugal, scroll or reciprocating type. Reciprocating chillers, however, are phasing out slowly.
            2. DX System: These systems use refrigerant throughout between compressor and cooling coils. Screw, scroll and reciprocating compressors are generally used for this application.
        ii. System Selection: The selection of a specific refrigeration system requires careful analysis. The following parameters influence the selection:
            1. Life Cycle Cost Analysis of different chilled water systems.
            2. System Capacity, kW (Tons of Refrigeration).
            3. System Application, Examples: Animal Research Facilities, Classrooms, or Office Buildings.
            4. New System or Addition to Existing System.
        iii. Refrigerant Selection**:** The refrigerant shall be fully compatible with all local, state, and federal regulations. The refrigeration equipment selection shall be based on the new EPA approved hydrochlorofluoro-carbon refrigerants, such as, HCFC 123, HFC 134a, and HCFC 22. The latest versions of ASHRAE Standards 15 and 34 shall be followed to ensure its full compliance.
            1. Provide adequate ventilation of the mechanical equipment rooms and make provisions for emergency shutdown of equipment.
            2. Provide refrigerant vapor detectors and monitors, and alarms local as well as at ECC. A minimum of two self-contained breathing apparatus shall also be provided, one inside and one outside the mechanical equipment room.
            3. Low pressure chillers shall be vented to outdoors.
11. Central Chilled Water Plant
    a. Number of Chillers**:** The central chilled water plant shall comprise of at least two chillers, unless the system is to be cross connected to an existing chilled water plant. In that case, a single chiller may be used. The chillers shall be identical in size and design, except for the following considerations:
        i. Part Load Conditions: If the anticipated part load conditions justify the use of uneven sizes. The designer shall prepare the necessary cooling load profile demonstrating the need for doing so.

ii. Operating Costs: Do a life cycle cost analysis of the following chillers. Based on the favorable results for energy consumption and/or electrical demand charges, a selection of the chiller plant shall be made.
1. All electric chillers
2. All absorption chillers
3. Combination of electric and absorption chillers

b. Chiller Performance**:** The electric, water-cooled, centrifugal, and rotary-screw chillers shall be scheduled on drawings in accordance with the ARI Standard 550/590-98 for the lowest full load KW/ton which can be met by at least three manufacturers.

c. Standby Equipment
i. Chillers: Standby refrigeration equipment or arbitrary safety margin as a spare capacity is not required.
ii. Pumps: When two chillers are used to handle the total cooling load, one condenser water and one chilled water pump shall be provided to act as standby. When three or more chillers are used, no standby pumps will be required.

d. Additional Design Considerations
i. New Construction: A designated reserve space shall be provided, and shown on the drawings, for a future chiller equal in size to the largest machine being furnished. The space planning shall also include space for circulating pumps, cooling tower, electrical starter, etc. associated with future chiller. The chilled and condenser water mains and the chilled water distribution loop shall be sized, valved, and arranged to accommodate the future chiller.
ii. Chiller/Accessories Arrangement:
1. The piping arrangement shall be such that each chiller shall have a dedicated condenser water pump, cooling tower fan and a primary chilled water pump. When the chiller is not in operation, its dedicated condenser and chilled water pumps and the cooling tower fan shall also be inoperative.
2. Chilled water and condenser water circuits shall be piped for complete functional flexibility. Provide cross connections for the chilled water pumps and condenser water pumps, suctions and discharges, and condenser inlets and outlets, and cooling tower cells to increase flexibility. Provide automatic on/off valves, where necessary, to avoid pumping through an inoperative chiller and cooling tower. Investigate the need to provide primary/secondary piping-pumping arrangement as described below.

3. Primary/Secondary Arrangement: The chilled water flow through the evaporators shall be kept constant. The chilled water flow through the cooling coils, however, shall be variable with automatic, two-way, modulating control valves controlling the flow.
4. Tertiary Arrangement: Where multiple buildings are served by the central chilled water plant, or where all cooling load is not scheduled to be activated at the same time, tertiary piping/pumping arrangement shall be provided. Tertiary systems shall also be considered where the secondary pumping head could become excessive without tertiary pumps or where the chilled water temperature entering the system need to be higher than the chilled water temperature leaving the chiller(s).
5. Chilled Water Temperature Differential: The chilled water temperature differential across the chiller shall be optimized but shall not be less than 10 degrees F. Consider the impact of piping, pumping cost, cooling coil performance, and chilled water piping arrangement in order to optimize the chilled water differential.
6. Chilled Water Filter: A cartridge type of water filters shall be provided across pumps. The filter capacity shall not be more than 1 percent of the total flow in circulation.
7. Cooling Tower Water Treatment: Water treatment for the cooling towers shall be provided and the equipment location shall be shown on the drawings. The equipment location shall make an allowance for the chemical drums (in use and spares) and their movement in and out of the chilled water plant. If the chemicals feed pump is interlocked with the cooling tower flow, the treatment chemicals may be put into the condenser return piping. If a cooling tower bypass is included in the system design, the bypass should discharge into the cooling tower basin(s) rather than into the cooling tower outlet piping.

12. DX Refrigeration Systems
    a. Application: The use of chilled water from a stand-alone chiller or a central chilled water plant is preferable, if available. DX systems should be carefully evaluated under the following situations:
        i. The facility does not have a central chilled water plant with any spare capacity.
        ii. The central chilled water plant shuts down in winter. But a few specific areas require mechanical cooling.
        iii. Connections to the existing chilled water plant could involve extensive chilled water piping and pumping costs, thereby making use of the existing chilled water plant impractical.

iv. Whenever the project involves special applications requiring back-up cooling, for the following areas:
1. Telephone Equipment Rooms
2. Elevator Machine Rooms

b. Equipment Selection**:** If the capacity range permits, the chiller selection shall be based on the multiple compressors and refrigeration circuits to ensure energy conservation and operation flexibility.

c. Refrigerant Piping: Wherever the system configuration involves field installed piping, the same shall be sized and designed in accordance with the manufacturer's recommendations. The complete piping layout, including all accessories, such as double suction risers, solenoid valves, expansion valves, oil separators, refrigerant receivers, etc., shall be shown clearly on the floor plans and schematic layout drawings.

13. Refrigeration Systems for Animal Research Areas

a. Areas Served: Separate refrigeration system(s) shall be provided to serve animal research areas including holding areas, surgical facilities, laboratories, and associated support areas.

b. System Type**:** To facilitate easy start in mild weather, the dedicated chiller(s) serving animal research areas shall be air cooled water chiller with dedicated chilled water distribution piping and pumps. The chilled water system for animal research areas shall be cross connected to the central chilled water plant, if existing.

c. System Capacity/Operation**:**

i. Capacity: The chiller(s) capacity shall match the cooling load required for the animal research areas. Two chillers of equal capacity with chilled water at about 42 degrees F shall be provided. However, with a central chilled water plant, in service, a single chiller with multiple compressors can be used.

ii. Operation: The air-cooled chillers shall be the prime source of cooling for the animal research areas because they require lower space temperatures. The chiller and the air handling unit operate at temperatures, typically 42 degrees F or below compared to normally 44-45 degrees F temperatures associated with a central chilled water plant.

14. Freeze Protection-Chilled Water System

a. Adequate protection shall be provided for chilled water to avoid potential problems associated with freeze up.

15. Chilled Water: The following measures shall be evaluated to protect the coils and pipes carrying chilled water. Select one or more options, as deemed necessary.

a. Heat Tracing: All exposed chilled water piping shall be heat traced with thermostatically controlled electric tape.

16. Freeze Protection-Condenser Water System
    a. The cooling towers shall be winterized as follows:
        i. Provide thermostatically controlled basin heaters if the cooling tower is scheduled to remain in operation during fall and winter. All exposed condenser water piping shall be heat traced.
        ii. Partial Draining: Only exposed condenser water shall be drained during fall and winter when the cooling tower is not in operation. With this measure, it will be possible to partially save the water chemicals. A set of drain and isolation valves will be required to facilitate draining.
17. Documentation Requirements
    a. Schematic Diagram: A schematic control diagram of the entire chilled water system shall be shown on one drawing so that there is a comprehensive understanding of the system configuration and the intended mode of operation.
    b. Partial and incomplete diagrams shall be unacceptable. The diagram shall be complete with, but not limited to, the following:
        i. Temperature sensors
        ii. Control valves
        iii. Pressure Differential Assemblies
        iv. Expansion tanks
        v. Air separators
        vi. All valves and piping specialties not shown on standard details
        vii. Water Filters
        viii. Chemical Feeders
        ix. Water treatment for cooling towers
        x. Measures taken to prevent dead heading of pumps
        xi. Water make-up connections
        xii. Drain Connections
        xiii. Variable speed drives, if required
        xiv. Flow control and measuring devices
18. Equipment Rooms
    a. Space Planning: Ample space shall be provided to service and repair the refrigeration equipment. The tube pull space shall be clearly shown on the drawings. Overhead hoist beams shall be provided, as required, to facilitate the removal of the condenser and evaporator heads. Piping shall have the necessary offsets and mechanical couplings or flanges to permit removal of heads and tubes.
    b. The floor plans and at least two cross sections shall be drawn at 1/4" scale to show clearances and access spaces. The designer shall not rely on the construction shop drawings to be assured of the adequate maintenance space.
        i. Calculations: Pump head calculations shall be based on the actual piping layout and takeoffs. Add an additional 10 percent safety factor to the total calculated pump head.

ii. Piping Supports: For the condenser and chilled water pipe sizes 10 inches and larger, the pipe support shall be engineered and all supports/hanger sizes and locations shall be shown on drawings. In addition, the interface of the upper attachment of the pipe hangers shall be coordinated with the structural drawings; auxiliary steel, as required to support the pipe hangers from the building structure, shall be shown on the drawings. The designer shall submit complete engineering calculations to EMU to ensure compliance with this requirement.

19. Variable Speed Drives
    a. Variable/Constant Flow Pumps: With variable flow chilled water systems, variable speed drive pumps shall be used for the secondary and tertiary chilled water distribution systems. The designer shall ensure that all distribution pumps are equipped with the variable speed drive packages rather than only one or two pumps within the distribution system. This design feature is essential to ensure that all secondary pumps, while operating in parallel, run at the same speed and double up the same pumping head.
    b. Existing Systems: The use of the variable speed drives shall be carefully evaluated for the existing chilled systems, where three-way automatic control valves are furnished for the cooling coils. For such retrofit applications, the existing 3-way valves must also be changed to 2-way automatic control valves and pressure differential assembly along with variable speed drive for pumps.

20. Automatic Temperature Control Systems
    a. General
        i. Except for small HVAC systems or factory-packaged systems, the automatic control systems shall be Direct Digital Controls (DDC) type with pneumatic, electric, or electronic operators. Final selection of the type of controls shall be confirmed with EMU before proceeding with complete design of automatic temperature control system.
        ii. The flow and control diagrams for air, water, glycol, and steam systems and the sequence of operation for all HVAC systems and sub-systems shall be shown on the drawings. The diagrams shall show complete operating description including starting, interlocks, part load operation, smoke control features, volumetric controls, alarms, and emergency or power failure associated with operation of HVAC systems.
        iii. Temperature and humidity controls may be electric (small jobs only), electronic, or pneumatic.

iv. Air compressors for pneumatic control systems shall be arranged to operate automatically with emergency generator power in the event of utility power failure. Sizing of the air compressor is the responsibility of the control system manufacturer based on a 1/3 on 2/3 off run time basis as outlined in the specification. However, the electrical service and location of the compressor must be shown on drawings.

v. Outdoor air temperature and humidity sensors shall be located outdoors, and not in outdoor air ducts. Provide shading for sensors. Sensors shall be protected from direct sunlight and be easily accessible.

vi. Show local temperature control panels and distributed control panels on drawings.

vii. Control wiring and tubing shall be concealed. Use of wire mold will not be acceptable.

viii. Room Temperature Control: As many as three (3) perimeter rooms of similar use, size and exposure may be grouped into one (1) zone. As many as four small interior rooms of similar function and load may be grouped into one zone. Laboratories or other spaces, in which the supply air volume is based on special air requirements, shall also have individual temperature control.

ix. Atrium smoke control systems shall not be controlled through the building automation systems.

b. Building Automation System (BAS)

i. The drawings or specifications must include ECC and DDC schedules of input and output points for all HVAC systems and equipment as well as equipment of other trades requiring remote control and monitoring. Also, show a suitable location in each mechanical room for a Distributed Control Panel (DCP). Provide emergency power for the BAS and each DCP.

ii. Hand-off-automatic switch, furnished by electrical, shall be provided for all motor starters on systems controlled from the BAS and DCP(s). Where applicable, the electrical designer must specify the input from utility company meters for electrical demand limiting programs and for monitoring the commercial power supply. When the optimized start/stop program is used, designer must furnish necessary load inputs to the BAS.

iii. Uninterruptible Power System (UPS): A continuous on-line UPS shall be provided for BAS while commercial power is being switched over to emergency power.

iv. The following points shall be monitored and controlled if the associated equipment is provided:

1. Remote start/stop control, status indication with alarm and total run time for:
    a. Air handling unit supply and return fans
    b. Exhaust fans. Minor fans may be omitted
    c. Pumps for chilled water, condenser water, hot water and glycol energy recovery loop
2. Remote reset control for:
    a. Supply air temperatures
    b. Chilled water, hot water, and condenser water temperatures
3. Air Handling Unit temperatures (Db):
    a. Return air
    b. Mixed air entering air-handling unit
    c. Air leaving preheat coil
    d. Air leaving air-handling unit
    e. Air leaving heat recovery coil
    f. Supply air leaving air-to-air heat exchanger
4. Status alarms for:
    a. Filters
    b. Freezestats and duct-mounted smoke detectors
    c. Vibration switch for cooling tower fan
    d. High temperature for lab and dietetic refrigerators/ freezers
    e. Low main control air pressure
    f. High discharge air static pressure
    g. High/Low condenser water pH
    h. Water chiller cutout alarms
    i. Vacuum systems, compressed air and emergency generators, domestic hot water systems, constant temperature rooms, dietetic, elevators and other remote mechanical and electrical systems such as building lighting level sewage pumps, etc., as applicable
    j. High and low temperature for each animal room and/or cubicles
5. Pressure indication with high/low alarm:
    a. High pressure steam service
6. Chilled water plant:
    a. Chilled water supply and return temperatures and flow rates
    b. Condenser water supply and return temperatures and flow rates

7. Heat Exchangers:
    a. Heating water supply temperatures and flow rate
    b. Glycol/water system, supply and return

v. The following programs shall be provided as applicable:
1. Time initiated programs
2. Optimum start/stop
3. Enthalpy optimization/economizers
4. Chilled water plant optimization
5. Automatic restart of equipment sequence after power outage and upon resumption of commercial power service, and upon application of emergency power
6. Power demand limiting
7. Preventative maintenance instruction
8. Fire emergency
9. Calculating of air flows, water flows, tonnage (BTU, Tons, Lb./Hr., CFM, GPM), etc.
10. Optimization control of hot deck and cold deck temperatures; air quantity control in VAV systems
11. Optimization of lighting use
12. Computer Diagnostic and Testing Programs: To test all programs and report malfunctions down to specific items or circuits

21. Emergency Power for HVAC
    a. List of HVAC Equipment on Emergency Power
        i. The engineering control center (ECC), each field cabinet, the control air compressors and dryers, and any electric controls for systems on emergency power
        ii. Fan motors for critical laboratory fume hoods.
        iii. All supply and exhaust fans, water chillers and chilled water circulating pumps and controls for Animal Research Facility.
        iv. Heating equipment as required by NFPA 99.
        v. Ventilation/cooling equipment for emergency generator rooms and elevator machine rooms.
        vi. Steam Condensate Return Pumps
        vii. Back up HVAC system for telephone equipment rooms
        viii. Computer Room A/C systems
        ix. Exhaust fans for Battery Charging Areas
        x. Exhaust fans for Flammable Storage Rooms
        xi. Electric tape for heat tracing of exposed chilled water piping and condenser water requiring freeze protection
        xii. Atrium smoke control equipment

Section 23 00 09 Energy Conservation

1. General
   a. The project design including mechanical systems shall use the provisions outlined in this document, and criteria from other technical disciplines, to meet the requirements of the International Energy Code, current edition.
2. Building Thermal Envelope
   a. New Construction: The building thermal envelope for the new EMU facilities shall be energy efficient to minimize the heat gain and loss due to conduction and solar radiation. The building envelope shall minimize the air leakage to and from the occupied spaces and shall also ensure condensation control.
      i. Recommended "U" Values: The following represents the recommended "U" values of walls, roof and glass, and the Shading Coefficients (SCs) of glass for new construction. These values should be used to meet the overall U factor, for the building gross wall area, defined under the next paragraph.
   b. U values shall meet or exceed those identified in the most current edition of the International Energy Code.
3. Design Features
   a. In addition to energy studies and decisions made in conjunction with economic analysis, the following features shall be incorporated without the need for an economic analysis.
      i. Air conditioning systems shall be designed to operate below 48 °F outdoor temperature without refrigeration, unless such refrigeration is used effectively as a heat pump with overall energy savings.
      ii. Heat recovery devices, comprising of either air to air plate heat exchangers or glycol run around loop heat recovery coils shall be installed in all 100% outdoor air systems with capacities in excess of 3000 CFM. The exhaust air systems, from which the heat is to be extracted, shall also have capacity in excess of 3000 CFM per exhaust fan, and shall be of continuously operating type. Controls for heat recovery system shall be designed to avoid defeating any "free cooling" (economizer cycle) operation. Controls shall also be designed to avoid overheating the outdoor air during mild or warm weather and prevent icing of the exhaust air coil below 32 °F ambient air temperatures.

4. Estimated Energy Consumption: With the final design submission (construction documents - or working drawings - phase), the A/E shall estimate the energy consumption of the proposed new building(s) and provide a value in Watts per gross square meter per year (British Thermal Units (BTU) per gross square foot (GSF) for each building. To accomplish this task the building(s) operation shall be simulated on the basis of the actual configurations of the mechanical/electrical systems designed to save them.

End of Division 23 – Heating, Ventilating and Air Conditioning (HVAC)