TECHNICAL MANUAL

# MECHANICAL DESIGN HEATING, VENTILATING, AND AIR-CONDITIONING

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HEADQUARTERS, DEPARTMENT OF THE ARMY

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## REPRODUCTION AUTHORIZATION/RESTRICTIONS

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## MECHANICAL DESIGN

# HEATING, VENTILATING, AND AIR-CONDITIONING



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*This manual supersedes TM 5-810-1, dated 1 August 1983.

# CHAPTER 1

# GENERAL

## 1-1. Purpose

This manual provides guidelines for design of mechanical systems for heating, ventilating, and air conditioning (HVAC).

## 1-2. Scope

This manual delineates only those features of HVAC design that are unique in their application, or reflect policies that have been established through regulations, directives, and other published media through the Department of Defense. Unless otherwise specified, all designs will comply with the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbooks and Military Handbook 1008A.

## 1-3. References

Appendix A contains a list of references used in this manual.

## 1-4. Basic principles

All designs will be based on the following basic principles.

*a*. Interior design conditions selected, including temperature, humidity, filtration, ventilation, air changes, etc., will be suitable for the intended occupancy.

*b*. System selections will conform to the life cycle cost criteria and energy targets specified in the Architectural and Engineering Instructions (AEI). The designer will evaluate all energy conservation items that appear to have potential for savings such as heat recovery for HVAC and service water heating, economizer cycles, and plastic door strips for loading docks and include those items in the design that are life cycle cost effective.

*c*. The design will be as simple as possible.

*d*. Adequate space will be provided to access items that require maintenance such as filters, coils and drain pans, and strainers.

## 1-5. Waivers

Request for waiver from criteria, where a valid need exists and where an alternate solution involving sound engineering is available, will be submitted to HQUSACE (CEMP-ET), Washington, DC 20314-1000. Request for waiver must include justification, life cycle cost analysis, criteria used, and other pertinent data.

## 1-6. Redundant systems

Request for approval to provide redundant HVAC systems, where system failure would result in unusually high cost repair/replacement of equipment or process housed in subject facility or disruption of activities vital to national security, will be submitted to HQUSACE in accordance with paragraph 1-5. A waiver is not required where redundant HVAC systems are required by other applicable criteria.

# CHAPTER 2

# FUNDAMENTALS

## 2-1. Calculations

*a. Heating Calculations.* Anticipated internal and solar heat gains will be excluded from heating calculations. The calculated size of equipment and distribution system may be increased by up to 30 percent to compensate for morning recovery due to night setback.

*b. Cooling Calculations.* Cooling calculations will be prepared using either the Transfer Function Method (TFM) or the Cooling Load Temperature Differential/Cooling Load Factors (CLTD/CLF) Method as described in the ASHRAE Handbook Fundamentals. The calculated size of equipment and distribution system may be increased by up to 10 percent to compensate for morning recovery due to night setforward or by up to 10 percent to compensate for unanticipated loads or changes in space usage; however, size of equipment and distribution system will not be increased by more than 15 percent total. A psychometric plot of each air conditioning system will be submitted along with the calculations. All points in the conditioning process should be clearly identified on the psychometric chart and verification of both sensible, latent, and total capacity should be shown using the appropriate data from the chart. Sensible, latent, and total capacity requirements will be given for each cooling coil specified. For applications where reheat is required for humidity control, the capacity of the reheat will be equal to the total internal sensible heat generated in the area served.

## 2-2. Design conditions

*a.* Outdoor *Design Conditions.*

*(1)* The outdoor design temperature for comfort coolingwill be the 2.5 percent dry bulb and the corresponding mean coincident wet bulb temperature as listed in TM 5-785. The selection of evaporative equipment, however, will be based on the 2.5 percent wet bulb temperature. For applications where maintaining indoor temperature or humidity conditions is critical, the designer may use the corresponding 1.0 percent temperatures. For the selection of condensers and condensing units that will be subjected to unusually high radiation heat gain, 5ºF will be added to the dry bulb temperature specified above.

*(2)* The outdoor design temperature for comfort heating will be the 97.5 percent dry bulb temperature as listed in TM 5-785. For applications where maintaining indoor temperature or humidity conditions is critical, the designer may substitute the 99.0 percent temperature for the 97.5 percent temperature.

*b. Indoor Design Conditions.*

*(1)* The indoor design temperature for comfort cooling will be 15ºF less than the 2.5 percent outdoor design temperature, but will not be lower than 75ºF or higher than 78ºF. The indoor design specific humidity will not exceed the outdoor design specific humidity; otherwise, the indoor design relative humidity will be 50 percent. The indoor design temperature provided by evaporative cooling or comfort mechanical ventilation will be 80°F.

*(2)* The indoor design temperature for comfort heating will be 68°F in areas with low levels of physical activity and 55°F in areas with moderate to high levels of physical activity. The indoor design temperature for freeze protection will be 40°F. Where the indoor relative humidity is expected to fall below 20 percent for extended periods, humidification maybe added to restore the indoor relative humidity to a maximum of 30 percent.

## 2-3. Infiltration

Where acceptable, air distribution systems for central HVAC systems will be designed to maintain a slight positive pressure within the area served in order to reduce or eliminate infiltration.

## 2-4. Ventilation

Ventilation will be in accordance with ASHRAE Standard 62.

*a.* A complete ventilation analysis will be included in each HVAC design analysis. The ventilation analysis will include a room-by-room breakdown of the anticipated number of occupants, the amount of ventilation air required, and any applicable adjustments such as multiple spaces factor, intermittent or variable occupancy factor, flow reduction factor, and ventilation effectiveness factor. Where these adjustments are significant, alternatives will be explored to reduce life cycle costs. Ventilation for variable air volume systems will ensure proper ventilation rates at low and high system air flow.

***b.*** A ventilation schedule will be included on the drawings, perhaps combined with the diffuser/register schedule. This schedule should assist the building occupants when performing future minor renovations. The schedule will list the total supply air and the number of anticipated occupants for each room. A footnote will be added to each schedule indicating that the number of occupants is provided for information purposes only.

*c.* Outdoor air intakes will be located in areas where the potential for air contamination is lowest. Basic guidelines include the following:

*(1)* Maximize distance between intakes and cooling towers, plumbing vents, loading docks, traffic, etc.

*(2)* Maintain a minimum distance of 30 feet between intakes and exhausts, more if possible.

*(3)* Locate intakes and exhausts on different building faces.

*d.* Where desirable, designer may incorporate a purge mode into system design. This mode could be used, for example, to purge the building with outside air during off-hours or to purge the affected zone during building maintenance, such as painting.

*e.* Where practical, photocopiers and laser printers should be located in a separate room. This room should not be directly conditioned, but should be maintained at a negative pressure relative to adjacent areas by exhausting air from these adjacent areas to the outdoors.

## 2-5. Filtration

For administrative facilities, commercial facilities, and similar occupancies where indoor air quality is of primary concern, the combined supply air, including return and outside air, will be filtered by a combination of 25 to 30 percent efficient prefilter(s) and 80 to 85 percent efficient final filter(s) as determined by the dust spot test specified in ASHRAE Standard 52. Due to the decrease in system airflow as the pressure drop across the filters increases, fans should be sized for the "dirty" ( filter condition. This will ensure that the fan has adequate capacity to deliver the design airflow as the filter becomes loaded. In addition, in order to ensure that this fan capacity is “available”, test and balance criteria in the appropriate Corps of Engineers Guide Specification (CEGS) requires that actual airflows after balancing are greater than (typically up to 10 percent) or equal to those shown on the drawings.

## 2-6. Duct design

*a.* The use of the T-Method for duct design is encouraged due to its ability to optimize both first and operational costs of the entire air distribution system. Either the T-Method or the Static Regain Method will be used to design ducts for VAV systems. The use of round or oval prefabricated duct is recommended. Round/oval prefabricated duct reduces leakage and friction losses, therefore reducing the amount of conditioning and fan energy required. The additional material cost for round/oval prefabricated duct would be at least partially offset by reduced installation cost and time.

***b.*** The following types of construction will not be used where subterranean termite infestations are known to exist:

*(1)* Buildings with sub-slab or intra-slab HVAC ducts.

*(2)* Buildings with plenum-type, subfloor HVAC systems, as currently defined in Federal Housing Administration minimum acceptable construction criteria guidance.

*(3)* Buildings with HVAC ducts in enclosed crawl spaces that are exposed to the ground.

*(4)* Buildings with other HVAC systems where any part of the ducting is in contact with or exposed to the ground.

## 2-7. Controls

Design of HVAC controls will be in accordance with TM 5-815-3.

## 2-8. Noise and vibration control

Design of HVAC systems with respect to noise and vibration control will be in accordance with TM 5-805-4. Acoustical duct liner should be used only where other methods of noise control are not feasible.

## 2-9. Seismic protection

Design of HVAC systems with respect to seismic protection will be in accordance with TM 5-809-10.

## 2-10. Radon

All new facilities will be designed and constructed to include the following features to reduce the potential radon exposure to the facility occupants:

*a.* All penetrations through foundation wall/slab will be sealed in accordance with TM 5-805-6 or with prefabricated seals designed for the prevention of radon entry.

***b.*** Ventilation system will be designed to maintain positive pressure within the occupied spaces where practical.

*c.* Subslab area design will include provisions required to later complete a subslab ventilation system to maintain that area at a negative pressure of 0.5 to 1.0 inches water column at the vent inlet in comparison to the occupied spaces. One method that has proven to be successful consists of a 4-inch diameter PVC suction pipe per each 1500 ft 2 of slab area. The pipe can be embedded into the aggregate through the slab and capped at the top. Perforated pipe may be embedded into the aggregate instead of solid pipe in order to provide improved distribution of air intake. Care should be taken to provide access to air intake for areas isolated by footings or grade beams. These vent pipes can be uncapped and attached to exhaust fan if radon mitigation is required after construction.

## 2-11. Refrigerants

The current version of the appropriate CEGS should be carefully reviewed by the designer prior to the selection of mechanical refrigeration equipment. Current and anticipated future restrictions limit or prohibit the use of ozone-depleting substances. For designs where the refurbishment or demolition of mechanical refrigeration equipment is involved, the designer will provide detailed step-by-step guidance and diagrams for this work that complies with the recommendations of ASHRAE Guideline 3.

## 2-12. Special criteria for humid areas

The following criteria will be used in the design of air conditioned facilities located in areas where the wet bulb temperature is 67ºF or higher for over 3,000 hours and the outside design relative humidity is 50 percent or higher, where the wet bulb temperature is 73ºF or higher for over l500 hours and the outside design relative humidity is 50 percent or higher, based on 2.5 percent dry bulb and 5.0 percent wet bulb temperatures.

*a. System Selection.* Air-conditioning will be provided by an all air system. The system may consist of a central air-handling unit with chilled water coils or a unitary direct expansion-type unit(s) capable of controlling the dew point of the supply air for all load conditions. Systems such as variable volume constant temperature, bypass variable air volume, variable temperature constant volume, and terminal air blenders should be considered. In addition to life cycle cost considerations, system selection will be based on the capability of the air-conditioning system to control the humidity in the conditioned space continuously under full load and part load conditions. System selection will be supported by an energy analysis computer program that will consider the latent-heat gain due to vapor flow through the building structure, to air bypassed through cooling coils, and to the dehumidification performance of the air-conditioning system under varying external and internal load conditions. Low sensible loads and high latent loads (relatively cool cloudy days) will, in some cases, cause inside relative himidity to be higher than desired. If analysis indicates that this condition will occur, reheat will be used. Recovered heat will be used for reheat where possible.

*b. Fan Coil Units.* Room fan coil units will not be used unless dehumidified ventilation air is supplied to each unit or separately to the space served by the unit and positive pressure is maintained in the space.

*c. Air Handling Units.* Draw-through type air handling units will be specified in order to use the fan energy for reheat. Air distribution system will be designed to prevent infiltration at the highest anticipated sustained prevailing wind.

*d. Ventilution.* Outside air will be conditioned at all times through a continuously operating air-conditioning system.

*e. Air and Water Temperatures.* The supply air temperature and quantity, and chilled water temperature will be based on the sensible heat factor, coil bypass factor, and apparatus dew point.

*f. Outdoor Design Temperatures.* The one percent wet bulb temperature will be used in cooling calculations and equipment selections.

*g.* Closets *and Storage Areas in Air Conditioned Facilities.* These areas should be either directly air conditioned or provided with exhaust to transfer conditioned air from adjacent spaces.

*h. Reheat.* Where reheat is required to maintain indoor relative humidity below 60 percent, heat recovery, such as reclamation of condenser heat should be considered in life cycle cost analysis.

*i. Economizer Cycle.* Economizer cycle will generally not be used due to the high moisture content of outside air.

## 2-13. Water treatment

Determination of the local water composition is essential to the design of water treatment for mechancial systems. A water analysis may be available from the using agency. If an analysis is unavailable, the designer will obtain a sample of the raw water. The sample will be tested and the results will be included within the specifications. Water treatment systems for boilers will be designed in accordance with TM 5-650. Water treatment systems for cooling towers will provide for prevention of corrosion, scale, and biological formations. Closed chilled water systems, hot water systems, and dual temperature systems will be treated for initial fill with allowances for the addition of chemicals as needed.

# CHAPTER 3

# SYSTEMS

## 3-1 System selection

The eligibility of a facility for air conditioning, dehumidification, evaporative cooling, mechanical ventilation, or heating will be determined in accordance with chapter 4.

## 3-2 Heating systems

Steam or high temperature water will be used for large distribution systems.

*a. Steam. Single* pipe systems will not be used. For safety, low pressure steam (15 psig and below) will be used where terminal equipment is installed in occupied areas. High pressure steam (above 15 psig) unit heaters may be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 12 feet above floor level.

*b. Hydronic* Systems.

*(1)* Gravity flow hot water systems will not be used.

*(2)* For safety, low temperature hot water (250ºF and below) will be used where terminal equipment is installed in occupied areas. Medium temperature hot water (up to 350ºF) or high temperature hot water (up to 450ºF) unit heaters may be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 12 feet above floor level.

*(3)* Freeze protection will be automatically provided by operating circulating pumps when outside temperature drops below 35ºF or will be provided by the addition of an appropriate antifreeze solution.

*c. Warm Air.*

*(1)* Gravity flow warm air furnaces will not be used. Direct fired heaters are prohibited in areas subject to hazardous concentrations of flammable gas, vapors, or dust.

*(2)* Ductwork will be provided for distribution with forced air units where throws would otherwise exceed 60 feet, or where several rooms are to be heated.

*d. Infrared Radiant Heating.* Infrared radiant heating will be considered for high bay areas or where spot heating is required. Gas, oil, and electricity may be considered as fuel sources. Night setback of these systems will be considered where experience has demonstrated that it is cost effective.

*e. Electric Resistance Heating.* Electric resistance heating is not permitted except under the conditions outlined herein:

*(1) Family Housing.* Electrical resistance heating may be used where a bathroom has been added and the existing heating system is inadequate to heat the addition, or where a bathroom has been added and it is unreasonable from an engineering or economic position to extend the existing heating system to the new area. All electric resistance or infrared heaters in family housing bathrooms should be controlled by an occupant activated time switch with a maximum time setting of 30 minutes. Family housing served exclusively by the Bonneville Power Authority (BPA) may use resistance heating in all rooms, provided detailed engineering study has shown electric heating to be the most economical method on a life cycle cost basis, with demand charges fully accounted for. BPA has stated in writing that adequate power will be available for housing in the foreseeable future. Thermostats with a maximum setting of 75°F will be used throughout the housing project, and the heating system will be equipped with a positive cutoff above 65ºF outdoor temperature.

*(2) Small Remote Facilities.* Electrical resistance heating may be used where all of the following criteria are met: the individual facility (total building) heating load is less than 15,000 Btu per hour provided natural gas is not available within a reasonable distance; the facility has a maximum total energy consumption of less than 60,000 Btu per square foot per year (nominal 40-hour week use) or less than 118,000 Btu per square foot per year (around-the-clock use); the facility is equipped with thermostats with a maximum setting of 75ºF and a positive cutoff above 65ºF outdoor temperature; and all facilities occupied less than 168 hours per week are to be equipped with a temperature setback to a maximum of 50ºF during all unoccupied periods. Small offices or duty stations located within larger unheated or partially heated buildings (e.g., warehouse office, dispatch office in a motor pool, duty room in an armory or reserve facility) requiring less than 15,000 Btu per hour, may use electric resistance heating under the conditions outlined above.

*(3) Noncritical Fuel Areas.* In geographical areas where at least 85 percent of the power is generated from noncritical sources such as hydroelectric, nuclear, or geothermal, electric resistance heating may be considered as an alternative in the life cycle cost analysis provided energy budgets outlined in e(2) above are not exceeded and high limit thermostats and setback controls are installed. Heat should be generated “off peak” through storage of low or medium temperature water and should be used directly

or indirectly as a source for a water source heat pump or a combination of the above.

## 3-3. Cooling systems

*a. Chilled Water.* The supply and return water temperature differential will be determined by life cycle cost analysis.

*b. Cooled Air.* To the extent practical, system air flow will be minimized. Integrated air conditioning and lighting systems will be used whenever the general lighting level is 100 footcandles or greater.

## 3-4. Comfort ventilation

Gravity ventilation is rarely adequate as a reliable source for comfort ventilation. It can be used in high-bay areas which are rarely occupied, such as storage buildings, or in areas which are difficult to ventilate, such as hangars. Nighttime air flushing of spaces, multi-speed fans, increased insulation, improved shading, and building site will be considered to improve the effectiveness of comfort ventilation. Where a waiver to provide air conditioning where not authorized is submitted in accordance with paragraph l-5, an hour-by-hour simulation of indoor conditions using comfort ventilation only will be included in the waiver request.

## 3-5. Evaporative cooling

Evaporative cooling will be used where the facility in question is eligible for air-conditioning, and evaporative cooling can provide the required indoor design conditions based on the appropriate outdoor design conditions. In many locations where evaporative cooling cannot provide the required indoor conditions year-round, it should be further considered where preliminary life cycle calculations show that it is cost effective as a supplement to the primary cooling system. For special applications where close temperature or humidity control is required, two stage evaporative cooling or indirect evaporative cooling will be considered in life cycle cost analysis as a supplement to, not in lieu of, primary cooling system.

## 3-6. Combination heating-cooling systems

Heating-cooling systems will be combined to avoid duplication of system elements and to reduce costs.

*a. All-Air Systems.* Where outdoor design temperatures are 20ºF or below, all air systems will be considered only in conjunction with double glazing, where sedentary activities are a minimum of 3 feet from the glass, and where proper peripheral air distribution is provided. Preheat coils will be used whenever the mixture of return air and ventilation air at outside design temperature is below 35 ºF.

*b. All-Water Systems.* Two-pipe dual-temperature systems will be considered for most comfort applications. Generally, three and four pipe systems cannot be justified for comfort applications and will not be used unless shown to be life cycle cost effective.

*c. Air-Water Systems.* Consideration should be given to combinations of air and water systems such as radiant heating supplemented with single zone interior air supply for ventilation; hydronic systems at the periphery of a build ing to offset skin transmission losses only, combined with the use of an air system for space cooling and ventilation loads.

*d. Heat Pumps.*

*(1)* When considering the use of heat pumps, a thorough engineering analysis is required. The requirement for possible additional power transmission and substation capacity, the added impact of demand charge power consumption and peak demands will be evaluated.

*(2)* Selection of heat pumps will be made in the following order: water source heat pumps, using wells and ponds as a heat source; air source heat pumps; and in the case where the perimeter spaces of a building must be heated and the interior cooled concurrently, water-to-air heat pumps utilizing a closed water loop system will be considered.

# CHAPTER 4

# APPLICATIONS

## 4-1. General

Where a facility will have areas requiring comfort conditions and areas requiring indoor design conditions that exceed the requirements for comfort conditions (computer rooms, electronic rooms, etc.), the areas requiring comfort conditions will be served by separate air distribution systems, or the primary air distribution systems will be controlled for comfort conditions and areas requiring conditions that exceed comfort conditions will have supplemental systems to provide additional conditioning as required. If, however, areas requiring comfort conditions require no more than 25 percent of the total air supply or comprise no more than 1,000 square feet of total floor space, the primary air distribution system may be controlled to meet the more demanding conditions. Where reheat is required for areas requiring close control, the reheat capacity will be equal to the total design sensible heat generated within the area served.

## 4-2. Administrative areas

Administrative areas, including those in facilities that are not otherwise eligible for air conditioning, such as warehouses, shops, and hangars, will be air conditioned only in locations where the dry bulb temperature is 80ºF or higher for over 350 hours per year.

## 4-3. Computer and electronic areas

*a. Computer Areas.* Indoor design conditions, including temperature and humidity limits, will deviate from those required for comfort conditioning only to the extent required to support the computers to be housed within the area. Other design considerations include the following:

*(1)* Where practical required cooling capacity will be provided by two or more smaller units in order to reduce energy consumption at partial cooling loads and to increase overall system reliability.

*(2)* Where an underfloor supply air plenum is used in conjunction with above ceiling return, the number and size of outlets in the raised floor will be based on 80 percent of the total supply air, the remaining 20 percent will be supplied to the room via cable cutouts in the raised floor. Supply registers specified will be suitable for installation in floors on which the movement of equipment is anticipated. Ceiling return registers will be located near heat producing equipment.

*b. Electronic Equipment Areas (Communication, Surveillance or Research).* Where area is eligible for comfort cooling, indoor design conditions, including temperature, humidity, and level of filtration, will deviate from those required for comfort conditioning only to the extent required to support the equipment to be housed within the area. Where area is not eligible for comfort cooling, air conditioning, indoor design conditions will not exceed those required for proper equipment operation, and conditioning will be limited to equipment housing or the smallest practical partitioned area.

## 4-4. Toilets, lockers, and utility closets

These areas will be maintained at a negative pressure relative to adjacent areas by exhausting air transferred from these adjacent areas to the outdoors. Where possible, the heating equipment capacity or energy consumption will not be increased by these areas. These areas will not be directly air-conditioned.

## 4-5. Smoking lounges

Smoking lounges will be maintained at a negative pressure relative to adjacent areas by exhausting air transferred from these adjacent areas to the outdoors. Where possible, the heating equipment capacity or energy consumption will not be increased by the smoking lounge. The smoking lounge will not be directly air-conditioned.

## 4-6. Vestibules

Vestibules may be heated to 50ºF to melt tracked-in snow in locations where conditions warrant. Otherwise, vestibules will not be heated or air-conditioned.

## 4-7. Equipment rooms

*a.* Equipment rooms will be properly ventilated. Equipment rooms will generally be provided with outside air intake louvers and thermostatically controlled exhaust fan. A supply fan will be used in lieu of an exhaust fan in rooms where atmospheric burners are located The fan will have a two-speed motor. The high speed capacity will limit the room dry bulb temperature to a maximum of 10ºF above the outdoor dry bulb temperature when both equipment and ambient loads are at their maximum peaks. The high speed will be activated 10°F below the maximum temperature at which the most sensitive item of equipment in the room can operate. The low speed will operate at 20ºF below that of the high speed.

*b.* Air-conditioning may be provided if life cycle cost effective to prevent severe corrosion in salt laden areas where, during the six warmest consecutive months, the wet bulb temperature is 73°F or higher for over 4,000 hours.

## 4-8. Battery rooms

Battery rooms will be provided with exhaust fan interlocked with battery charger so that the charger will not operate without ventilation and sired to prevent hydrogen concentration from exceeding 2 percent by volume. The power ventilation system for the battery room must be separate from ventilation for other spaces. Air recirculation in the battery room is prohibited. The fan motors must be outside the duct and battery room. Each blower will have a nonsparking fan. When two or more battery chargers are used in a room, multiple speed fan or multiple fans will be considered. The capacity of the exhaust fan will be determined as follows:

$$Q = 0.054 \times I \times N$$

Where:

Q = Required ventilation rate in $ft^3/min$

I = 0.21 x (capacity of the largest battery to be charged in ampere-hours) or 0.25 x (the maximum obtainable amperes from the charger), whichever is greater.

N = (number of batteries to be recharged at one time) (number of cells per battery). A single cell is normally 2 volts DC, therefore a normally has 3 cells and a 12-volt battery normally has 6 cells.

Areas used for battery storage in maintenance facilities will be ventilated at a minimum rate of 1.5 $ft^3/min/ft^2$, with care taken to ensure proper air distribution to and within the battery storage area.

## 4-9. Kitchens and dishwashing rooms

*a.* Ventilation will be the chief means of preventing heat, odors, and smoke from entering dining areas and other adjacent spaces. Evaporative cooling may be provided where effective. Spot air-conditioning or general air- conditioning may be provided to keep temperature in the work areas from exceeding 85°F, if the main portion of the facility is eligible for air-conditioning and the criteria for exhaust ventilation are met. A separate ventilation system for the dishwashing area will be provided Tempered (65 °F db min.) makeup air will be furnished for the rangehood exhaust. No more than 75 percent of air (excluding hood exhausts) will be recirculated in the kitchen at any time. Kitchen canopy hood exhaust ventilation rates will generally be 75 fpm for grease filter sections, and 50 fpm for open hood section, measured at the horizontal hood opening. As an alternative, internal baffle type canopy hood with peripheral slot and a slot velocity of 500 fpm is recommended. Supply and exhaust air fans wiIl be electrically interlocked and designed for 2-speed operation.

*b.* When substantial quantities of hot air exhausted from kitchen areas do not contain grease, consideration should be given to the use of air-to-air heat exchangers in order to recover as much energy as possible. In kitchens where heat rejected by refrigeration equipment is 50,000 Btu/hr or more, heat recovery will be evaluated.

*c.* Dishwasher room exhaust ducts will be as short as possible with direct runs to outside of building. Ductwork will have watertight joints and will have a drain line from the low point. Approximately 75 percent of the room air should be exhausted at the dishwasher with the remainder exhausted at the ceiling. Dishwashers normally have duct collar connections so that exhaust ducts can be attached directly.

## 4-10. Gymnasiums, indoor courts, and swimming pools

*a.* Enclosed handball and squash courts may be air conditioned. Otherwise, gymnasiums will not be air conditioned unless the dry bulb temperature exceeds 93°F for over l,300 hours and the wet bulb temperature is 73ºF or higher for over 800 hours, or the wet bulb temperature exceeds 73ºF for over 4,000 hours during the year. To reduce heating for locker rooms, transfer air from the gymnasium should be used.

*b.* Indoor swimming pool areas will be designed for year-round use. In order to conserve energy, the temperature of the air surrounding the pool should be as close as possible to the temperature of the water during the heating season; however, the pool area will not be air conditioned.

## 4-11. Living quarters

*a.* Variable air volume system with individual room thermostats will be considered as an alternative to individual fan coil units for dormitory-type quarters in the life cycle cost analysis.

*b.* Air-conditioning will be provided for the following types of facilities only in locations where during the six warmest months of the year the dry bulb temperature is 80 ºF or higher for over 650 hours or the wet bulb temperature is 67ºF or higher for over 800 hours:

*(1)* Fire Station Dormitories.
*(2)* Military Family Housing.
*(3)* Unaccompanied Enlisted Personnel Housing.
*(4)* Unaccompanied Officers' Personnel Housing.
*(5)* Temporary Lodging Facilities (Including the Administrative Areas).

## 4-12. Maintenance facilities

*a.* General Purpose Aircraft Hangars. Heating systems will be selected on the basis of the outside design temperatures as presented in table 4-1. Floor type unit heaters will introduce 20 percent outside air. The discharged air will be directed to cover the entire floor area so as to break up explosive pockets. Motor operated fresh air dampers will be provided for 100 percent outside air when desired. The capacity of heater fans will provide not less than six air changes per hour based on an artificial ceiling height of 15 ft. Mechanical exhaust ventilation consisting of not less than 30 air changes per hour will be provided for control rooms in alert hangars. In climates with winter design temperatures below 10ºF or where annual snowfall exceeds 20 inches, snow melting coils circulating heated antifreeze solution under hangar door trackswill be provided.

*Table 4-l. Heating System-Hangars.*

| Outside design temperature (°F db) | System Type Below |
|---|---|
| 0 ° | Radiant heating will be installed in the floor slab of the hangar area to provide 50% of the requirement, supplemented by floor- type air handling units. Between 1ºF and 40º floor-type air handling units will be provided. Overhead unfired unit heater may be used to supplement floor-type heaters where hangar width is greater than 150 ft. |
| Above 40º | None required. |
| Below 10º | Snow melting coils will be provided for door tracks. |

Note: Floor-type air handling units will be arranged to draw warm air from the top of the hangar for distribution at occupied level.

*b. Aircraft Maintenance Shops (Avionics).* Evaporative cooling is authorized where effective. Limited air-conditioning maybe provided for those functional areas where required for quality control of equipment, material, and task. In all cases, localized or spot air-conditioning may be provided at individual work stations; however, the entire shop area will not be air- conditioned.

## 4-13. Storage facilities

*a. General Purpose Warehouses.* Warehouses for storage of materials not subject to freezing should not be heated. For warehouses containing materials subject to freezing, heating systems will be designed to maintain an inside winter temperature of 40ºF. In warehouse areas with active employment, temperatures of 55°F will be maintained. Unit heaters and radiant heaters will be considered on an energy and life-cycle cost basis. Evaporative cooling may be provided in active warehouses where effective.

*b. Dehumidified Warehouse.*

*(1)* Where only humidity control is required, the life cycle cost analysis will compare dry desiccant type dehumidifier and refrigerated dehumidification. The dry desiccant type will consist of two stationary beds or will be the rotary type with operation alternating between drying and regeneration.

*(2)* Where both temperature and humidity control is required, a central air- conditioning system will be used.

## 4-14. Laboratories

*a.* HVAC systems will be designed so as to provide control over space temperature conditions including contaminants and fume control appropriate to the space function. Exhaust systems will be designed to remove toxic substances through fume hoods. Hood and system design will follow the recommendations of the American Conference of Government Industrial Hygienists Manual. Minimum design face velocities for hoods are based on the toxicity of the material being handled. Face velocities at the hood opening should be as follows: highly toxic substances at 125 fpm, general laboratory exhaust at 80 fpm, and non-toxic substances at 5 fpm.

*b.* Supply air quantities will be established based on the room cooling load and the exhaust requirements. Supply air intakes will be located with care to avoid cross contamination with exhaust air discharges. Consideration should also be given to air flow patterns influenced by adjacent buildings. Air supply, exhaust and automatic control systems will be designed to insure flexibility, so that changes in the use of space can be accommodated.

## 4-15. Hospitals

HVAC designs for hospitals will be in accordance with TM 5-838-2.

## 4-16. Commissaries

HVAC designs for commissaries will be in accordance with the AEI.

## 4-17. Laundries and dry cleaners

Ventilation will generally be the primary method of heat dissipation. Evaporative cooling may be provided where effective. Spot air-conditioning or general air-conditioning may be provided to keep the temperature in the work areas from exceeding 85ºF. Coil discharge temperatures used in spot cooling should be 50ºF dry bulb maximum for maximum dehumidification. Heat recovery equipment on exhaust air wilt be used to temper make-up air in cold weather.

## 4-18. Reserve centers

Typically, only a small portion of a reserve center is occupied during normal working hours, while the balance of the facility is utilized primarily for weekends only. The anticipated occupancy pattern will be considered when developing equipment layout and sequence of operation in order to ensure that overall life cycle cost is minimized.

## 4-19. Arts and crafts/skill development centers

These facilities may be air-conditioned provided the functions requiring above minimum ventilation rates (metal and woodworking shops) and having excessive heat releases (kilns and welding equipment) are not air-conditioned.

## 4-20. Other eligibility criteria

*a.* Air-conditioning will be provided for the following facilities only in locations where the dry bulb temperature is 80ºF or higher for over 650 hours or the wet bulb temperature is 67°F or higher for over 800 hours during the six warmest months of the year:

*(1)* Auditoriums and Theatres.
*(2)* Banks.
*(3)* Bowling Alleys.
*(4)* Chapels.
*(5)* Daycare Centers, Schools, and Libraries.
*(6)* Stores and Exchanges.
*(7)* Clubs and Dining Facilities.
*(8)* Post Offices.
*(9)* Indoor Target Ranges.

*b.* The following types of facilities are not eligible for air-conditioning regardless of weather conditions:

*(1)* Boiler Plants.
*(2)* Greenhouses.

# CHAPTER 5

# EQUIPMENT

## 5-1. Location of equipment

Air-conditioning equipment, including air handlers, compressors, pumps and associated equipment will be of the weatherized-type and installed outside of the facility where advantageous to life cycle cost. When comparing interior and exterior equipment installations in life cycle cost analysis, analysis will include additional building cost required to house interior equipment. Exterior water chilling and water cooling equipment will be designed to ensure adequate drainage for winterizing.

## 5-2. Chillers

Individual reciprocating machines will not exceed 200 tons capacity, and the total capacity of all reciprocating machines or packaged air conditioning units equipped with reciprocating compressors used for air conditioning a single facility will not exceed 400 tons. A single packaged unit will not contain more than eight compressors. Where multiple chillers are specified, a chilled water pump and a condenser pump will be provided for each chiller. Pumps will be piped in such a manner so as to be interchangeable. With the exception of the criteria listed herein, the number of chillers specified will be optimized in the life cycle cost analysis. In facilities when there is a combination of normal summer air-conditioning loads and year around air-conditioning loads, careful consideration will be given to the sizing of equipment and zoning so that the equipment specified can support the entire facility load during warm weather and a portion of the equipment may be essentially fully loaded during winter operations. In facilities when, because of the small size of the off-hours or the small winter load, it is impractical to operate the primary equipment in the central plant, an auxiliary refrigeration system may be provided. Heat recovery will be evaluated and used where life cycle cost effective.

*a. Reciprocating Compressors.*

*(1)* For chillers over 10 tons, only capacity control which reduces the power requirement as the load varies will be used.

*(2)* Compressors operating in parallel will have the normal oil level at the same elevation for all machines and the crankcases of these compressors will be provided with gas and oil equalizing lines. When compressors are connected in parallel, the hot-gas discharge lines will be so arranged that the oil from the common discharge line will not collect in an idle unit while the other units are running, and will be sized to provide an equal pressure drop between each machine and its respective condenser. The suction lines will return refrigerant gas and oil from the evaporator to the compressor during operation of the system, and will not allow oil or liquid refrigerant to be returned as slugs at any time. Suitable means will be provided for trapping oil in the common suction header to prevent oil slugs from collecting in the idle compressor.

*b. Centrifugal Compressors.* When a two-stage centrifugal compressor is selected, a refrigerant intercooler will also be required. For low temperature applications, where compressors with four or more stages may be needed, two-stage intercoolers will be used. Capacity control will be accomplished using methods which reduce energy consumption as the load is reduced. The final choice of the control will be based on an evaluation of life cycle costs.

*c. Helical Rotary (Screw) Compressor.* Screw compressors will utilize oil injection. An oil separator or sump and oil cooler will be included in the system. Since oil coolers assist the condenser in rejecting heat, the size of the refrigerant condenser can be reduced in size equal to the amount of heat extracted by the oil cooler.

*d. Electrical and Mechanical Drives.* The choice of drives for refrigeration equipment should be based on the availability and price of fuel, cost of electricity, or the capability of utilizing waste heat. The operating characteristics of the refrigeration compressor will be a major factor in determining the compatibility of the drive and compressor.

*(1)* In areas of high electric demand rates, an evaluation of the impact of air conditioning of the facilities' peak electric demand will be made to determine economic feasibility of electric drive.

*(2)* Where steam turbine drives are used, an evaluation using the exhaust steam of non-condensing turbines as the input to low pressure steam absorption refrigeration will be included in the life cycle cost analysis.

*(3)* Only split-shaft gas turbines will be used for air conditioning due to the poor starting characteristics of single-shaft machines. Whenever gas turbines are selected, an evaluation using exhaust gases to generate steam in a waste heat boiler to power absorption refrigeration will be included in the life cycle cost analysis.

*e. Absorption Refrigeration.*

*(1)* Absorption equipment should only be considered whenever waste steam is available from incineration of solid wastes, heat recovery engine or gas turbine exhausts, or exhaust from steam turbine drives for refrigeration compres- sors or electric generators.

*(2)* Absorption chillers must have the capability of operating at variable condenser water temperature without crystalization.

*(3)* Capacity control will be in the form of a throttling valve to modulate flow to the absorbent generator with chilled water temperature as well as an automatic steam

valve which reduces steam pressure and temperature, for energy efficient part load control.

*(4)* The use of two-stage absorption refrigeration will be considered whenever high pressure steam or high temperature water is available. The life cycle cost analysis will address the economic feasibility of using the higher first cost, two-stage machine.

## 5-3. Boilers

This paragraph provides criteria for gas and oil fired low temperature hot water boilers and low pressure steam boilers that are used primarily for single building applications. Central heating plants will be in accordance with TM 5-815-1.

*a. Boiler Types.*

*(1)* Cast iron boilers are available in sizes up to 13,000 MBtuh (1.3 x $10^7$ Btuh) gross output. Advantages include low maintenance and sectional construction.

*(2)* Steel firebox boilers may be of a fire tube or water tube design. A principal advantage is the capability of interchanging fuels such as coal for oil or gas if necessary. Capacities up to 23,500 MBtuh gross output are available.

*(3)* Whenever the fuel choice is either gas or oil and there is no likelihood of converting to coal, package boilers may be installed. Package boilers are either of a fire tube (including Scotch marine) or water tube design.

*b. Multiple Boiler Installations.*

*(1)* Boiler installations will be designed to be expandable when expansion is expected. Spare boilers and related axiliaries, to be used for future loads, will not be installed.

*(2)* The number and size of boilers should be selected to efficiently handle both the maximum winter design load and the minimum summer load. With the largest boiler off line, the remaining boiler(s) will be capable of carrying not less than 65 percent of the maximum winter design load. Where the smallest boiler installed has a capacity of more than twice the minimum summer load, consideration will be given to providing an additional boiler or hot water heater sized for the anticipated summer load.

*c. Steam Boiler Accessories.* A chemical feed system will be provided in accordance with TM 5-650 based on an analysis of the makeup water to be used. Depending upon the size of the installation and the pressure at which steam is generated, the inclusion of boiler accessories such as feedwater heaters to increase the steam generation cycle efficiency should be provided.

*d. Feedwater Heating Systems.*

*(1)* Heaters for the deaeration of feedwater will be installed for all installations with steam capacities in excess of 20,000 MBtuh, and should be considered for installations of 15,000 MBtuh to 20,000 MBtuh capacity where estimated makeup rates are 15% or more, or where the plant serves a number of buildings. Installations operating with either hot lime-soda or hot lime plus hot sodium zeolite softeners incorporating provisions for the deaeration of the treated water and condensate separately require no additional deaeration.

*(2)* Steel surge tanks will be provided for the storage of condensate and installed ahead of the feedwater heaters where the space heating load predominates, where large quantities of condensate are returned by condensate pumps, and where steam-driven auxiliaries are used. Surge tanks will be sized to provide 20 minutes storage of condensate based on boiler steaming capacity.

*(3)* Feedwater flow rate to the heater should equal the boiler demand. Pumps will be sized for feedwater requirement plus 10% to allow for pump cooling requirements.

*(4)* Feedwater heaters will be installed on elevated structures at such a height above the boiler feed pump suction that will prevent flashing at the pump inlet under the feedwater temperature conditions obtained. With a feed- water temperature of 212ºF and a back pressure on the feedwater heater of approximately 2 psi, the hydrostatic head on the feed pumps should be approximately 10 feet. Where the boiler feed is held at a temperature above 212 ºF, the hydrostatic head should be increased in proportion to the increased vapor pressure of the liquid. Feedwater heaters will be provided with a properly valved bypass to permit operation of the boilers at times when the heater is being serviced.

*e. Combustion Equipment.* The installation of combustion equipment, including burners and draft fans, will be in accordance with ASHRAE Handbooks, Underwriters Laboratory (UL), National Fire Protection Association (NFPA), and the recommendations of equipment manufacturers.

*(1) Gas Bunters.* All gas-fired equipment will be equipped with a burner which can be readily converted to burn an alternate fuel, as required in AR 420-49. Equipment utilizing gas will have a dual fuel capability.

*(2) Oil Burners.* The selection of oil burners will depend on the grade of the oil being burned, the size of the installation, and the need for modulating control. For light oil, atomizing will be accomplished utilizing oil pressure, air, or steam atomizing burners. For heavy oil, atomizing will be accomplished utilizing air or steam atomizing burners.

*(3) Stacks and Draft Requirements.* Heating installations will include either natural-draft chimneys or individual boiler mechanical fans with stub stacks. Where natural-draft stacks would be a hazard to aircraft or otherwise objectionable, mechanical-draft fans discharging into short stub stacks will be used.

*f. Fuel Selection and System Design.* The fuel selection and design will be made in accordance with the AEI, ASHRAE Handbooks, NFPA Standards, Military Handbook 1008A, and AR 420-49.

*g. Auxiliaries.* Where required, request for standby electric generators will be in accordance with paragraph 1-5. Boiler plant auxiliaries should, in general, be electrically driven; however, whenever an uninterrupted supply of steam is essential, one of the boilers should be provided with steam-driven auxiliaries. Individual forced and/or induced-draft fan; should be provided with each boiler unit. Pumps should include standby equipment in case of repairs.

*h. Flow Measurement.*

*(1)* Gas and oil meters will be provided for the boiler installation. Gas will be metered at each building. Oil meters shall be installed in both the fuel oil supply line and the fuel oil return line from the storage tank.

*(2)* The steam and hot water supply and condensate and hot water return will be metered for each building

# APPENDIX A

# REFERENCES

## Government Publications

*Department of Defense*

| | |
|---|---|
| Military Handbook 1008A | Fire Protection For Facilities Engineering, Design, and Construction |

*Department of the Army*

| | |
|---|---|
| AR 420-49 | Heating, Energy Selection and Fuel Storage, Distribution, and Dispensing Systems |
| TM 5-650 | Central Boiler Plants |
| TM 5-785 | Engineering Weather Data |
| TM 5-805-4 | Noise and Vibration Control For Mechanical Equipment |
| TM 5-805-6 | Calking and Sealing |
| TM 5-809-10 | Seismic Design For Buildings |
| TM 5-815-1 | Air Pollution Control Systems For Boilers and Incinerators |
| TM 5-815-3 | Heating, Ventilating, and Air Conditioning Control Systems |
| TM 5-838-2 | Army Health Facility Design |

*Army Corps of Engineers*

| | |
|---|---|
| AEI | Architectural and Engineering Instructions |

## Nongovernment Publications

American Conference of Governmental Industrial Hygienists, 650 Glenway Ave., Bldg. D-7, Cincinatti, OH 45211
Industrial Hygienists Manual

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Publication Sales, 1791 Tullie Circle, NE., Atlanta, GA 30329-2305

| | |
|---|---|
| Handbook | Equipment |
| Handbook | Fundamentals |
| Handbook | Refrigeration |
| Handbook | HVAC Systems and Applications |
| Guideline 3 | Reducing Emission of Fully Halogenated Chlorofluorocarbon (CFC) Refrigerants in Refrigeration and Air-Conditioning Equipment and Applications |
| Standard 52 | Air-Cleaning Devices Used in General Ventilation For Removing Particulate Matter |
| Standard 62 | Ventilation For Acceptable Indoor Air Quality |

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