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UNIFIED FACILITIES CRITERIA (UFC)

HEATING, VENTILATING, AND AIR CONDITIONING

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UNIFIED FACILITIES CRITERIA (UFC)

HEATING, VENTILATING, AND AIR CONDITIONING

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**
1	Oct 2006	Conform to UFC 1-300-01 and miscellaneous updates

This UFC supersedes TI 810-10, dated 1 February 1999.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

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CHAPTER 1 INTRODUCTION

1-1 **CRITERIA**. Unless otherwise specified either in this document or in the applicable UFGS, all designs shall comply with all applicable American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) criteria and guidance.

1-2 **AUTHORITY HAVING JURISDICTION.** The term "AHJ" as used in the codes and standards referenced in this UFC must mean the component office of responsibility, i.e., U.S. Army, HQ USACE/CECW-CE; U.S. Navy, NAVFACENGCOM HQ Code CHENG; U.S. Marine Corps, HQMC Code LFF-1; U.S. Air Force, HQ AFCESA/CES; Defense Logistics Agency (DLA), DSS-IP; National Imagery and Mapping Agency (NIMA), Security and Installations; and all other DOD components, Deputy Under Secretary of Defense for Installations via the DOD Committee on Heating, Ventilating, and Air Conditioning Engineering.

1-3 **BASIC PRINCIPLES.** The designer shall base all designs on the following basic principles:

1-3.1 Select interior design conditions, including temperature, humidity, filtration, ventilation, air changes, etc., that are suitable for the intended occupancy.

1-3.2 All design work shall be "sustainable" in accordance with ECB 2006-2.

1-3.3 Base system selections on life cycle cost effectiveness.

1-3.4 All DOD buildings must comply with the Energy Policy Act of 2005; whether new construction, replacement construction, or, to the greatest extent practical, refurbishment and system replacement.

1-3.5 Each design shall be as simple as possible.

1-3.6 Identify space necessary to access items that require maintenance, such as filters, coils and drain pans, strainers, and chillers on the drawings in three-dimensions.

1-3.7 Provide systems with the features necessary for successful testing, adjusting, and balancing, system commissioning, and for easy access for maintenance.

1-4 **WAIVERS**. Where a valid need exists and an alternate solution involving sound engineering is available, designers may submit requests for a criteria waiver to the applicable AHJ. Requests for waiver must include justification, life cycle cost analysis, energy compliance analysis, criteria used, and other pertinent data.

1-5 **REDUNDANT SYSTEMS**. Generally, redundant HVAC systems are not required. However, when a system failure would result in unusually high repair costs or replacement of process equipment, or when activities are disrupted that are vital to national security, the designer may submit a request for approval to the applicable respective service proponent's office in accordance with paragraph 1-4 to provide redundant HVAC systems. No waiver is required where redundant HVAC systems are specified by other applicable criteria.

CHAPTER 2 FUNDAMENTALS

2-1 **CALCULATIONS.** Perform multiple load calculations where suggested by ASHRAE in order to determine HVAC system requirements. One example where at least two load calculations are required is in order to verify comfort (including both indoor temperature and humidity levels) at the most challenging "low ambient sensible – peak ambient latent" design conditions for systems installed in humid areas as specified herein;

2-1.1 **Heating Load Calculations**. Exclude anticipated internal and solar heat gains from heating load calculations. Increase the calculated size of equipment and distribution system by up to 30 percent where necessary to compensate for morning recovery due to night setback.

2-1.2 **Cooling Load Calculations**. If necessary, increase the calculated size of equipment and distribution system(s) by up to 10 percent to compensate for morning recovery due to night set forward or by up to 10 percent to compensate for unanticipated loads or changes in space usage. Limit the total combined increase above the size calculated of equipment and distribution system(s) to 15 percent total. Submit a psychometric plot of each air-conditioning system along with the calculations. Clearly identify all points in the conditioning process on the psychrometric chart and verify the sensible, the latent, and the total cooling capacity using the appropriate data from the chart. List the sensible, latent, and total capacity requirements 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**.

2-2.1 **Outdoor Design Conditions.** Outdoor design conditions will be obtained at www.afccc.af.mil .

2-2.1.1 **Cooling.** The outdoor design temperature for comfort cooling will be the 1.0 percent dry bulb and the corresponding mean coincident wet bulb temperature. Base the selection of evaporative equipment on the 1.0 percent wet bulb temperature. For applications where maintaining indoor temperature or humidity conditions is critical, the designer may use the corresponding 0.4 percent temperatures. For the selection of condensers and condensing units that will be subjected to unusually high radiation heat gain, add 5 degrees F (3 degrees C) to the dry bulb temperature specified above.

2-2.1.2 **Heating.** The outdoor design temperature for comfort heating will be the 99 percent dry bulb temperature. For applications where maintaining indoor temperature or humidity conditions is critical, the designer may substitute the 99.6 percent temperature for the 99 percent temperature.

2-2.2 **Indoor Design Conditions.**

2-2.2.1 **Cooling.** The indoor design temperature for comfort cooling will be 15 degrees F (8 degrees C) less than the 1.0 percent outdoor design temperature, but will not be lower than 75 degrees F (24 degrees C) nor higher than 78 degrees F (26 degrees C). 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 degrees F (27 degrees C); the above requirements for specific humidity do not apply where evaporative cooling is used.

2-2.2.2 **Heating.** The indoor design temperature for comfort heating will be 68 degrees F (20 degrees C) in areas with low levels of physical activity and 55 degrees F (13 degrees C) in areas with moderate to high levels of physical activity. The indoor design temperature for freeze protection will be 40 degrees F (4 degrees C). Where the indoor relative humidity is expected to fall below 20 percent for extended periods, humidification may be added to increase the indoor relative humidity to 30 percent.

2-3 **INFILTRATION.** Design air distribution systems for central HVAC systems to maintain a slightly positive pressure within the area served in order to reduce or eliminate infiltration unless there is a valid need to maintain a negative pressure in that area.

2-4 **INDOOR AIR QUALITY (IAQ).** Ventilation for acceptable IAQ will be in accordance with ASHRAE Standard 62.1. Successful application of IAQ principles and criteria plays a role with regards to HVAC systems in ensuring occupant comfort and health. Good IAQ design practice increases worker productivity.

2-4.1 Provide a complete IAQ analysis in each HVAC design analysis. The analysis narrative should document a summary of all factors considered when making design choices regarding IAQ, including alternative ventilation solutions considered and reasons for the selection of the solution chosen. The IAQ analysis will also 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, the ventilation effectiveness factor, and any other factors such as high relative humidity. Where adjustments to typical ventilation rates are significant, explore design alternatives to reduce life cycle costs. Ventilation for variable air volume systems will ensure proper ventilation rates at low and high system airflow.

2-4.2 Provide a ventilation schedule on the drawings, perhaps combined with the diffuser/register schedule. This schedule should assist the building occupants when performing future renovations. List the total supply air and the number of anticipated occupants for each room in the schedule. Add a footnote to each schedule indicating that the number of occupants listed is for information purposes only.

2-4.3 Ventilation systems that are independent of the primary air supply and distribution systems can provide benefits such as increased humidity control, reduced amount of ventilation air than may be otherwise required, and increased equipment operating efficiency.

2-4.4 Where desirable, the 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 an area of the building undergoing maintenance, such as painting.

2-4.5 Where practical, locate photocopiers and laser printers in a separate room or group them together and provide local exhaust. Maintain the separate room at a negative pressure relative to adjacent areas by transferring air from these adjacent areas to the separate room. Do not add the air exhausted from the separate room or local exhaust to the return air or transfer it to any other areas.

2-5 **LIFE CYCLE COST ANALYSIS.** 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, thermal energy storage, desiccant dehumidification, plastic door strips for loading docks, etc., and include those items in the design that are life cycle cost effective. Ensure that all operation and maintenance costs are included in the life cycle cost analysis.

2-6 **ENERGY COMPLIANCE ANALYSIS.** In order to comply with the Energy Policy Act of 2005 (EPAct 2005), designs must achieve energy consumption levels that are a minimum of 30 percent below the level required by ASHRAE Standard 90.1. To demonstrate compliance with the EPAct 2005, the designer shall prepare an Energy Compliance Analysis (ECA) that includes a narrative of the path taken to demonstrate compliance (including reference to each paragraph in ASHRAE 90.1 that make up the proposed compliance "path"; identification of any software used to prepare calculations, input to and output from all calculations (with adequate explanation so that a reviewer can understand what all of the data means); a description of each energy conservation feature or change considered and the corresponding impact that it had on calculated energy consumption; and a description of the design proposed as a result of the ECA along with its calculated energy consumption.

2-7 **FILTRATION**. For administrative facilities, commercial facilities, and similar facility occupancy classifications where indoor air quality is of primary concern, it is preferable to filter the combined supply air, including return and outside air, with a combination of prefilter(s) with a MERV of 8 and final filter(s) with a MERV of 13 when tested in accordance with ASHRAE Standard 52.2. Where the use of extended surface nonsupported pocket (bag) or cartridge filters is unacceptable and satisfactory indoor quality can be achieved using extended surface filters, the use of prefilters is not required. Where practical, provide separate filtration or other means to clean the outdoor air, typically equivalent to that used for the combined air stream, prior to mixing it with the return air. Due to the decrease in system airflow as the pressure drop across the filter increases, size fans for the "dirty" filter condition. This will ensure that each fan has adequate capacity to deliver the design airflow as the filter becomes loaded.

2-8 **DUCT DESIGN**.

2-8.1 Use either the Static Regain or the T-Method method to design ducts for VAV systems. Use round and oval prefabricated duct wherever possible to reduce both leakage and friction losses. The additional material cost for round or oval prefabricated duct is often offset by reduced installation cost and time and reduced fan energy consumption and air leakage. Note that the use of oval ductwork is sometimes restricted to positive pressure applications.

2-8.2 Ensure that duct design incorporates all features necessary to accommodate testing, adjusting, and balancing (TAB). For example, provide adequate length of duct, both upstream and downstream of fans and coils. Show the necessary fittings, transitions, test ports, etc. required for successful TAB, for duct inspection and cleaning, and for damper access and inspection.

2-8.3 Do not use the following types of construction where the potential for subterranean termite infestation is high:

- Sub-slab or intra-slab HVAC ducts.
- Plenum-type, subfloor HVAC systems, as currently defined in Federal Housing Administration minimum acceptable construction criteria guidance.
- HVAC ducts in enclosed crawl spaces that are exposed to the ground.
- HVAC systems where any part of the ducting is in contact with or exposed to the ground.

2-9 **RADON**. Provisions for the prevention and mitigation of indoor radon will comply with UFC 3-490-04A Indoor Radon Prevention and Mitigation.

2-10 **CONTROLS**. Design HVAC controls in accordance with UFGS 23 09 23 Direct Digital Control for HVAC and Other local Building Systems and UFGS 25 10 10 Utility Monitoring and Control Systems (UMCS).

2-11 **SEISMIC PROTECTION.** Design HVAC systems with respect to seismic protection in accordance with the International Building Code.

2-12 **TESTING, ADJUSTING, AND BALANCING.** UFGS 23 05 93.00 10 Testing, Adjusting, and Balancing of HVAC Systems contains many of the requirements of HVAC testing, adjusting, and balancing including strict quality control guidelines that the construction contractor must meet in order to verify that the HVAC systems have been properly installed and operating as specified. All features required for successful TAB must be shown on the design drawings.

2-13 **COMMISSIONING**. The use of UFGS 23 08 00.00 10 Commissioning of HVAC Systems is mandatory for all Army and Air Force projects. Note that use of

UFGS 23 08 00.00 10 requires funding for the designer or a representative of a designer to participate in the commissioning at the project site.

2-14 **REFRIGERANTS**. Current and anticipated future restrictions limit or prohibit the use of ozone-depleting substances. ECB 2006-10 and the applicable UFGS have guidance regarding which refrigerants may be used. Additionally, some Installations have additional guidance regarding refrigerants. Consult with the applicable Contracting Officer's Representative to determine applicable guidance prior to the selecting mechanical refrigeration equipment. Where refurbishment or demolition of mechanical refrigeration equipment is involved, provide detailed step-by-step guidance and diagrams that comply with the recommendations of ASHRAE Handbook Refrigeration in the design.

2-15 **SPECIAL CRITERIA FOR HUMID AREAS**. Use the following criteria in the design of air-conditioned facilities located in areas where:

- the wet bulb temperature is 67 degrees F (19 degrees C) or higher for over 3,000 hours and the outside design relative humidity is 50 percent or higher, or

- the wet bulb temperature is 73 degrees F (23 degrees C) or higher for over 1500 hours and the outside design relative humidity is 50 percent or higher, based on 1.0 percent dry bulb and the corresponding mean coincident wet bulb temperature.

2-15.1 **System Selection.** HVAC systems will typically consist of a central air-handling unit with chilled water coils or unitary direct expansion-type unit(s) capable of controlling the dew point of the supply air for all load conditions. In addition to life cycle cost considerations, the designer must base system selection 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 a psychrometric 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. Peak latent load outdoor design conditions (the design wet bulb temperature and the mean-coincident dry bulb temperature) or low sensible loads and high latent loads (days with low sensible and high latent external loads) will, in some cases, cause inside relative humidity to be higher than desired. If analysis indicates that this condition will occur for an unacceptable period of time, reheat will be used. Use recovered heat for reheat where possible. Do not use face and bypass dampers for temperature control.

2-15.2 **Air Handling Units.** Specify draw-through type air-handling units in order to use the fan energy for reheat. Design the air distribution system to prevent infiltration at the highest anticipated sustained prevailing wind.

2-15.3 **VAV Units.** Use air throttling type VAV terminal units with an integral heating coil and a pressure independent air valve that modulates in response to space temperature.

2-15.4 **Ventilation.** Condition outdoor air at all times through a continually operating air-conditioning system. Consider using a separate system for outdoor air where necessary to maintain a sensible heat ratio of the mixed air entering the primary air-conditioning unit within the required limits of commercially available equipment and/or to reduce corrosive, salt-laden air from entering the primary air distribution system. Ensure that the building is maintained under a slightly positive pressure to minimize infiltration to the greatest extent possible.

2-15.5 **Air and Water Temperatures.** Base the supply air temperature and quantity, and chilled water temperature on the sensible heat factor, coil bypass factor, apparatus dew point, and outdoor humidity ratio.

2-15.6 **Outdoor Design Temperatures.** Use the one percent wet bulb temperature in cooling calculations and equipment selections.

2-15.7 **Closets And Storage In Air Conditioned Facilities.** These areas should be either directly air conditioned or provided with exhausts to transfer conditioned air from adjacent spaces.

2-15.8 **Reheat.** Where reheat is required to maintain indoor relative humidity below 60 percent, consider heat recovery, such as reclamation of condenser heat, in life cycle cost analysis.

2-15.9 **Economizer.** Economizer cycles generally will not be used due to the high moisture content of outside air.

2-15.10 **Penetrations Of Conditioned Envelope And Thermal Bridging.** Considerable moisture often enters the conditioned envelope both through penetrations for items such as pipes and conduits or as condensation as a result of thermal bridging at locations such as door and window frames and intersections of walls or walls and roofs. Provide details on the drawings for penetrations and potential thermal bridges.

2-16 **WATER TREATMENT**. The local water composition is essential to the design of water treatment for mechanical systems. A water analysis may be available from the using agency. If an analysis is unavailable, obtain a sample of the raw water. Test the sample and include the results in the applicable contract specifications. Design water treatment systems for boilers in accordance with UFC 3-430-02FA Central Steam Boiler Plants, or UFC 3-430-04FA High Temperature Water Heating Systems, for Army and Air Force. Provide water treatment systems for cooling towers for prevention of corrosion, scale, and biological formations. In most cases, a water treatment system is required for closed chilled-water systems, hot water systems, or dual-temperature systems.

2-17 **MECHANICAL VENTILATION FOR INDUSTRIAL APPLICATIONS.** For applications not covered by ASHRAE criteria, use the ACGIH Industrial Ventilation, A Manual of Recommended Practice.

CHAPTER 3 SYSTEMS

3-1 **SYSTEM SELECTION**. The following determines eligibility of a facility for air conditioning, dehumidification, evaporative cooling, mechanical ventilation, or heating.

3-2 **HEATING SYSTEMS**. Use steam or high-temperature water for large distribution systems.

3-2.1 **Steam**. Do not use single-pipe systems. For safety purposes, use low-pressure steam (15 psig [100 kPa gage] and below) where terminal equipment is installed in occupied areas. High-pressure steam (above 15 psig [100 kPa gage]) unit heaters may be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 13 feet (4 meters) above floor level.

3-2.2 **Hydronic Systems**.

3-2.2.1 Do not use gravity flow hot-water systems.

3-2.2.2 For safety purposes, use low-temperature hot water (250 degrees F [120 degrees C] and below) where terminal equipment is installed in occupied areas. Medium-temperature hot water (350 to 420 degrees F [120 to 175 degrees C]) or high-temperature hot water (350 to 400 degrees F [175 to 200 degrees C]) unit heaters may be used for space heating in areas such as garages, warehouses, and hangars where the discharge outlets are a minimum of 13 feet (4 meters) above floor level.

3-2.2.3 Freeze protection will be automatically provided by operating circulating pumps when outside temperature drops below 35 degrees F (2 degrees C) or will be provided by the addition of an appropriate antifreeze solution.

3-2.3 **Warm Air.** Do not use gravity flow warm air furnaces. Direct-fired heaters are prohibited in areas subject to hazardous concentrations of flammable gas, vapors, or dust.

3-2.4 **Infrared Radiant Heating**. Consider infrared radiant heating for high-bay areas or where spot heating is required. Gas, oil, and electricity may be considered as fuel sources. Use night setback where it is both appropriate and cost effective.

3-2.5 **Electric Resistance Heating.** Do not use electric resistance heating except where permitted in the following circumstances:

3-2.5.1 **Family Housing**. Electric 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. Provide an occupant-activated time switch with a maximum time setting of 30 minutes for electric resistance or infrared heaters in family housing bathrooms. Use thermostats with a maximum setting of 75 degrees F (24 degrees C) throughout the housing project.

3-2.5.2 **Small Remote Facilities**. Electric 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 (4 kW) 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 (190 kilowatt-hrs per square meter) per year (nominal 40-hour week use) or less than 118,000 Btu per square foot (1,340,00 kJ per square meter) per year (around-the-clock use);

- The facility is equipped with thermostats with a maximum setting of 75 degrees F (24 degrees C) and a positive cutoff above 65 degrees F (18 degrees C) outdoor temperature; and

- All facilities occupied less than 168 hours per week must be equipped with a temperature setback to a maximum of 50 degrees F (10 degrees C) 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 (4kW) may use electric resistance heating under the conditions outlined above.

3-3 **COOLING SYSTEMS.** When used as the only means of cooling, fan-coil units can rarely provide adequate dehumidification for the ventilation loads and their use in this manner is not recommended.

3-3.1 **Chilled Water.** Determine the optimum supply and return water temperature differential by life cycle cost analysis.

3-3.2 **Cooled Air.** To the extent practical, minimize system airflow. Use integrated air conditioning and lighting systems whenever the general lighting level is 100 foot-candles (1000 lux) or greater.

3-3.3 **Comfort Ventilation.** Gravity ventilation is rarely adequate as a reliable source for comfort ventilation. It can be used in high-bay areas that are rarely occupied, such as storage buildings, or in areas that are difficult to ventilate, such as hangars. Consider nighttime air flushing of spaces, multi-speed fans, increased insulation, improved shading, and building site to improve the effectiveness of comfort ventilation. If a waiver to provide air conditioning in an area not authorized is submitted in accordance with paragraph 1-4, an hour-by-hour simulation of indoor conditions using comfort ventilation only will be included in the waiver request.

3-3.4 **Evaporative Cooling.** Use evaporative cooling 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, give further consideration to its use as a supplement to the primary cooling system when preliminary life cycle calculations show the supplementary system to be cost effective. For special applications where close temperature or humidity control is required, consider two-stage evaporative cooling or indirect evaporative cooling in the life cycle cost analysis as a supplement to, not in lieu of, the primary cooling system.

3-4 **COMBINATION HEATING-COOLING SYSTEMS.** Combine heating-cooling systems to avoid duplication of system elements and to reduce costs. The limitations of fan-coil units with regards to latent loads associated with simply providing adequate ventilation for occupancies such living quarters make them unsuitable as the only means of cooling and dehumidification in most locations and for most occupancies.

3-4.1 **All Air Systems.** Where outdoor design temperatures are 20 degrees F (-6 degrees C) or below, consider all air systems only in conjunction with double glazing, where sedentary activities are a minimum of 3 feet (1 meter) from the glass, and where proper peripheral air distribution is provided. Use preheat coils whenever the mixture of return air and ventilation air at outside design temperature is below 35 degrees F (2 degrees C).

3-4.2 **All Water Systems.** Use two-pipe dual-temperature systems for comfort applications where feasible. Four-pipe systems may be used where two-pipe systems are not capable of providing the specified indoor design conditions. Generally, three-pipe systems cannot be justified for comfort applications and will not be used.

3-4.3 **Air-Water Systems.** Consider 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 building to offset skin transmission losses only, combined with the use of an air system for space cooling and ventilation loads.

3-4.4 **Heat Pumps.** When considering the use of heat pumps, perform a thorough engineering analysis. The requirement for possible additional power transmission and substation capacity, the added impact of demand charge power consumption, and peak demands must all be evaluated. Select heat pumps on the basis of life cycle cost effectiveness and include the following types, including combinations, where advantageous:

- ground source heat pumps, using wells or ponds as a heat source or perhaps imbedding a closed-loop heat rejection circuit in a parking lot as a “heat exchanger.”

- 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 air source heat pumps

3-4.5 **Radiant Heating and Cooling.** Radiant heating and cooling systems are gaining wider acceptance among HVAC designers. The designer should carefully review the most current design guidance from both ASHRAE and manufacturers’ literature prior to designing these systems, as they have many unique design characteristics.

3-5 **DESSICANT DEHUMIDIFICATION.** Both the ASHRAE Handbook Fundamentals and Handbook Applications describe several applications where desiccant dehumidification should be considered. These applications include instances where the latent load is large in comparison to the sensible load and instances where the energy costs to regenerate the desiccant is low relative to the energy costs required to dehumidify the air by chilling it below its dewpoint.

3-6 **THERMAL ENERGY STORAGE.** Consider using thermal energy storage (TES) where, for example, it could reduce peak power demand charges, provide additional cooling capacity where it is more life cycle cost effective than adding cooling equipment, or provide life cycle cost effective redundancy necessary to ensure reliability for critical applications. The hourly cooling load for the facility along with the hourly power consumption of the installation must be determined in order to design TES. Ensure that the supply water from the storage tank is at or below the required entering water temperature of all cooling coils during the last hour that the TES will be used at the outdoor design conditions specified. Where “ice-on-coil” is used as the method for TES, the loss in efficiency that occurs when chilling water to a lower design temperature must be factored into the life cycle cost analysis. This loss in efficiency may be somewhat offset by the lower temperature of the air entering the condenser during the hours when the system is “recharging.” For facilities where a water tank is required, it may be advantageous to specify a tank suitable for storing chilled water.

CHAPTER 4 APPLICATIONS

4-1 **GENERAL.** The requirements pertaining to eligibility in this section are usually necessary to comply with the energy consumption levels mandated herein. The hourly data necessary to determine eligibility is located at www.afccc.af.mil .

4-2 **MIXED OCCUPANCIES.** In those cases where a facility will have areas requiring comfort conditions and areas requiring indoor design conditions that exceed the requirements for comfort (control rooms, electronic rooms, etc.), use separate cooling system(s) for the areas requiring the more stringent conditions, or use system(s) that provide the comfort conditions with supplemental system(s) that provide required conditioning for the applications served. If, however, areas requiring comfort conditions require no more than 25 percent of the total cooling capacity or comprise no more than 1,000 square feet (100 square meters) of total floor space, the primary air-distribution system may be controlled to meet the more stringent conditions. Where reheat is necessary for areas requiring close control, size the reheat capacity so that it is equal to the total design sensible heat generated within the area served.

4-3 **ADMINISTRATIVE AREAS.** Generally, 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 80 degrees F (27 degrees C) or higher for over 350 hours per year.

4-4 **COMPUTER AND ELECTRONIC EQUIPMENT AREAS.** Deviate from the indoor design conditions required for comfort conditioning, including temperature and humidity limits, only to the extent required to support the computers and electronic equipment, including communication, surveillance, and research related equipment, to be housed within the area. If practical, use two or more smaller units to satisfy the required cooling capacity. This will generally reduce energy consumption at partial cooling loads and will also increase overall system reliability. Where an under-floor supply air plenum is used in conjunction with above ceiling return, design the number and size of outlets in the raised floor to deliver 80 percent of the total supply air. The remaining 20 percent of the supply air should be routed to the room via cable cutouts in the raised floor. Specify supply registers suitable for installation in floors on which it is anticipated that equipment will be moved. Locate ceiling return registers near heat producing equipment.

4-5 **TOILETS, LOCKERS, AND UTILITY CLOSETS.** Maintain these areas 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.

4-6 **VESTIBULES.** Vestibules may be heated to 50 degrees F (10 degrees C) to melt tracked-in snow in locations where conditions warrant. Otherwise, vestibules will not be heated or air conditioned.

4-7 **ATTICS.** Where attics are used in facilities that will be air conditioned, the attic shall be designed to achieve the maximum natural ventilation.

4-8 **EQUIPMENT ROOMS.** Equipment rooms shall be provided with door(s) on the building exterior that are sized to accommodate all maintenance and equipment replacement anticipated throughout the life of the building. Where a refrigerating system is housed within the equipment room, the design of the room shall comply with ASHRAE 15. Otherwise, the design of the equipment room shall comply with the following:

4-8.1 **Mechanical Ventilation.** Equipment rooms will usually be ventilated using outside air intake louvers and a thermostatically controlled exhaust fan. Use a supply fan in lieu of an exhaust fan in rooms where atmospheric burners are located. The ventilation fan will have a two-speed motor, which is sized, at the high speed, to have adequate capacity to limit the room dry bulb temperature to a maximum of 10 degrees F (6 degrees C) above the outdoor dry bulb temperature when both equipment and ambient loads are at their maximum peaks. The high speed will be activated 10 degrees F (6 degrees C) below the maximum temperature at which the most sensitive item of equipment in the room can operate. The low speed will operate at 20 degrees F (11 degrees C) below that of the high speed.

4-8.2 **Air Conditioning.** Air conditioning may be provided where 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 degrees F (23 degrees C) or higher for over 4,000 hours.

4-9 **BATTERY ROOMS.** Provide battery rooms with an exhaust fan interlocked with the battery charger so that the charger will not operate without ventilation. Size the exhaust fan to prevent hydrogen concentration in the room 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. Consider using a multiple speed fan or multiple fans when the room is designed for two or more battery chargers. Size the exhaust fan as follows:

Q = 0.053 x I x N

Where:

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

(Q = 0.025 x I x N Where: Q equals the required ventilation rate in l/sec.)

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) x (number of cells per battery). A single cell is normally 2 volts DC. Therefore, a 6-volt battery 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 $ft^3/min/ft^2$ (7.6 $l/sec/m^2$), with care taken to ensure proper air distribution to and within the battery storage area.

4-10 KITCHENS AND DISHWASHING ROOMS.

4-10.1 Ventilation will be the chief means of preventing heat, odors, and smoke from entering dining areas and other adjacent spaces. Provide evaporative cooling where effective. Spot air conditioning or general air conditioning may be provided to keep temperature in the work areas from exceeding 85 degrees F (29 degrees C), if the main portion of the facility is air conditioned and the criteria for exhaust ventilation are met. Provide a separate ventilation system for the dishwashing area. Furnish tempered 65 degrees F db min (18 degrees C db min) makeup air for the range hood exhaust. Do not recirculate more than 75 percent of air (excluding hood exhausts) in the kitchen at any time. Kitchen canopy hood exhaust ventilation rates will generally be 75 fpm (0.4 m/s) for grease filter sections, and 50 fpm (0.25 m/s) 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 (2.5 m/s) is recommended. Use electrically interlocked supply and exhaust air fans designed for 2-speed operation.

4-10.2 When substantial quantities of hot air exhausted from kitchen areas do not contain grease, consider using air-to-air heat exchangers in order to recover as much energy as possible. Evaluate the use of heat recovery in kitchens where heat rejected by refrigeration equipment is 50,000 Btu/hr (15 kW) or more.

4-10.3 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 will 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.

4-11 GYMNASIUMS, INDOOR COURTS, AND NATATORIUMS.

4-11.1 Enclosed handball and squash courts may be air conditioned. Generally, gymnasiums will not be air conditioned unless the dry bulb temperature exceeds 93 degrees F (34 degrees C) for over 1,300 hours and the wet bulb temperature is 73 degrees F (23 degrees C) or higher for over 800 hours, or the wet bulb temperature exceeds 73 degrees F (23 degrees C) for over 4,000 hours per year. Where feasible, use transfer air from the gymnasium to condition the locker rooms thereby reducing energy consumption.

4-11.2 Design natatoriums 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. ASHRAE Handbook Applications addresses the many unique considerations that must be addressed when designing natatoriums.

4-12 MAINTENANCE FACILITIES.

4-12.1 **General Purpose Aircraft Hangars.** Select heating systems on the basis of the outdoor design temperatures as presented in table 4-1. Floor-type unit heaters will introduce 20 percent outside air. Direct the discharged air to cover the entire floor area to break up explosive pockets. Provide motor-operated fresh air dampers 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 feet (5 meters). In alert hangers, provide mechanical exhaust ventilation consisting of not less than 30 air changes per hour for control. In climates with winter design temperatures below 10 degrees F (-12 degrees C) or where annual snowfall exceeds 20 inches (50 cm), provide snow-melting coils circulating heated antifreeze solution under hangar door tracks.

Table 4-1. Heating System - Hangars

Outside Design Temperature	System Type
0 degrees F (-18 degrees C) and below	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 1 degrees F and 40 degrees F (-17 degrees C and 4 degrees C).	Floor-type air-handling units will be provided. Overhead and unfired unit heaters may be used to supplement floor-type heaters where hangar width is greater than 150 ft (45 meters).
Above 40 degrees F (4 degrees C).	None required.

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

4-12.2 **Aircraft Maintenance Shops (Avionics).** Where effective, evaporative cooling may be used. Provide air conditioning 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 workstations; however, the entire shop area will not be air conditioned.

4-13 STORAGE FACILITIES.

4-13.1 **General Purpose Warehouses.** Do not heat warehouses used to store materials not subject to freezing. For warehouses containing materials subject to freezing, design heating systems to maintain an inside winter temperature of 40 degrees F (4 degrees C). In warehouse areas with active employment, temperatures of 55 degrees F (13 degrees C) will be maintained.

Consider both unit heaters and radiant heaters as alternatives in the life cycle cost analysis. Evaporative cooling may be provided in active warehouses where effective.

4-13.2 **Dehumidified Warehouse.** Where only humidity control is required, compare dry desiccant-type dehumidifier and refrigerated dehumidification in the life cycle cost analysis. The dry desiccant type will consist of two stationary beds or will be the rotary type with operation alternating between drying and refrigeration. Where both temperature and humidity control are required, use a central air conditioning system.

4-14 LABORITORIES

4-14.1 Design HVAC systems to provide control over space temperature conditions including contaminants and fume control appropriate to the space function. Provide exhaust systems with fume hoods to remove toxic substances as near to the source of the fumes as practical. Hood and system design will follow the recommendations of the American Conference of Government Industrial Hygienists Manual. Base minimum design face velocities for hoods on the toxicity of the material being handled. Face velocities at the hood opening should be as follows: highly toxic substances at 125 fpm (0.65 m/s), general laboratory exhaust at 80 fpm (0.45 m/s), and non-toxic substances at 5 fpm (0.025 m/s).

4-14.2 Base the amount of supply air on the room-cooling load and all exhaust requirements. Locate supply air intakes with care to avoid cross contamination with exhaust air discharges. Design air supply, exhaust and automatic control systems to provide flexibility for potential changes in the use of space.

4-15 **HOSPITALS.** HVAC designs for hospitals will be in accordance with UFC 4-510-01 Medical Military Facilities.

4-16 **COMMISSARIES.** HVAC designs for commissaries will be in accordance with the TI 800-01 Design Criteria.

4-17 **LAUNDRIES AND DRY CLEANERS.** Mechanical 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 85 degrees F (29 degrees C). Coil discharge temperatures used in spot cooling should be 50 degrees F (10 degrees C) dry bulb maximum for maximum dehumidification. Where feasible, use heat recovery equipment on exhaust air to temper makeup air in cold weather. Design clothes dryer exhaust venting in accordance with ETL 1110-3-483, Clothes Dryer Exhaust.

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 used primarily for weekends only. Consider the anticipated occupancy pattern when developing equipment layout and sequence of operation in order to ensure that overall life cycle cost is minimized. Otherwise, HVAC design shall be in accordance with UFC 4-171-05 Army Reserve Facilities.

4-19 **ARTS AND CRAFTS/SKILL DEVELOPMENT CENTERS**. These facilities may be air conditioned provided the functions require ventilation rates beyond that based on the number of occupants only (such as metal and woodworking shops) or where excessive heat releases are generated by equipment housed in the facility (such as kilns and welding equipment).

4-20 **UNIQUE ELIGIBILITY REQUIREMENTS FOR HAWAII.** For facilities over 500 square feet (465 square meters), a feasibility study shall be prepared prior to the start of design to determine whether the use of mechanical or natural ventilation in lieu of air conditioning will provide acceptable comfort conditions. Otherwise, air conditioning is recommended.

4-21 **ELIGIBILITY FOR AIR CONDITIONING OF OTHER FACILITY TYPES.**

4-21.1 Provide air conditioning for the following types of facilities generally in locations where the dry bulb temperature is 80 degrees F (27 degrees C) or higher for over 650 hours or the wet bulb temperature is 67 degrees F (19 degrees C) or higher for over 800 hours per year:

- Fire Station Dormitories.
- Military Family Housing.
- Unaccompanied Enlisted Personnel Housing.
- Unaccompanied Officers' Personnel Housing.
- Temporary Lodging Facilities (including the Administrative Areas).

4-21.2 Air conditioning is recommended for the following types of facilities where the dry bulb temperature is 80 degrees F (27 degrees C) or higher for over 350 hours per year:

- Dining Facilities
- General Classrooms of Schools
- Indoor target ranges

4-21.3 Air conditioning is recommended for the following facilities **only** in locations where the dry bulb temperature is 80 degrees F (27 degrees C) or higher for over 650 hours or the wet bulb temperature is 67 degrees F (19 degrees C) or higher for over 800 hours per year:

- Auditoriums and Theatres

- Banks
- Bowling Alleys
- Chapels
- Daycare Centers, Schools, and Libraries
- Stores and Exchanges
- Clubs and Dining Facilities
- Post Offices
- Indoor Target Ranges
- Fire station dormitories
- Housing or lodging facilities

4-21.4 Air conditioning is not recommended for the following facilities regardless of weather conditions:

- Motor vehicle storage garages
- Showers
- Special areas requiring high ventilation rates
- Vehicle storage areas of crash and fire stations
- Boiler plants
- Greenhouses

CHAPTER 5 EQUIPMENT

5-1 **LOCATION OF EQUIPMENT.** Specify air-conditioning equipment, including air handlers, compressors, pumps and associated equipment that is suitable for outdoor installation where life cycle cost effective. When comparing interior and exterior equipment installations in life cycle cost analysis, include all associated building costs to house interior equipment in the analysis, but also include in the consideration the longer expected life of indoor equipment. Provide details on the drawings necessary to ensure drainage for “winterizing” equipment where appropriate. When evaluating costs, provide an allowance for costs due to failure to winterize outdoor equipment properly, similar to the cost of insurance to offset the unexpected costs associated with a sudden cold snap or electric heat-tracing cable failure.

5-2. **CHILLERS.** Individual reciprocating machines will not exceed 200 tons (700kW) capacity, and the total capacity of all reciprocating machines or packaged air-conditioning units equipped with reciprocating compressor used for air conditioning a single facility will not exceed 400 tons (1400kW). A single packaged unit will not contain more than eight compressors. Where multiple chillers are specified, provide a chilled water pump and a condenser pump for each chiller. With the exception of the criteria listed herein, the number of chillers specified will be optimized in the life cycle cost analysis. Where there is a combination of normal summer air-conditioning loads and year-round air-conditioning loads optimize system zones and size system components to 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. Use heat recovery where it is life cycle cost effective.

5-2.1 **Reciprocating Compressors.**

5-2.1.1 For chillers over 10 tons (35 kW), use capacity control that reduces the power requirement as the load varies.

5-2.1.2 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, arrange the hot-gas discharge lines so that the oil from the common discharge line will not collect in an idle unit while the other units are running, and size the lines 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. Provide means for trapping oil in the common suction header to prevent oil slugs from collecting in the idle compressor.

5-2.2 **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. Use capacity control methods to reduce energy consumption as the load is reduced to minimize life cycle costs.

5-2.3 **Helical Rotary (Screw) Compressor.** Screw compressors will use oil injection. An oil separator or sump and oil cooler will be included in the system. Oil coolers assist the condenser in rejecting heat, so the refrigerant condenser can be reduced in capacity equal to the amount of heat extracted by the oil cooler.

5-2.4 **Electrical and Mechanical Drives.** Base the choice of drives for refrigeration equipment on the availability and price of fuel, cost of electricity, or the capability of using waste heat. The operating characteristics of the refrigeration compressor are typically a major factor in determining the compatibility of the drive and compressor.

5-2.4.1 In areas of high electric demand rates, evaluate the impact of air conditioning of the facilities' peak electric demand to determine economic feasibility of electric drive. Compare this to the cost per kWh, installation peak load, and any demand charges or incentives provided by the utility serving the installation. Deregulation in the electric utility industry may change the cost structure paid by the installation, so take into account any known or potential changes that may result from deregulation.

5-2.4.2 Where steam turbine drives are used, evaluate using the exhaust steam of non-condensing turbines as the input to low pressure steam absorption refrigeration in the life cycle cost analysis.

5-2.4.3 Use only split-shaft gas turbines for air conditioning due to the poor starting characteristics of single-shaft machines. Whenever gas turbines are used, evaluate using exhaust gases to generate steam in a waste heat boiler to power absorption refrigeration in the life cycle cost analysis.

5-2.5 **Absorption Refrigeration.**

5-2.5.1 Consider absorption equipment only where waste steam from incineration of solid wastes, heat recovery engine or gas turbine exhausts, or exhaust from steam turbine drives for refrigeration compressors or electric generators are available.

5-2.5.2 Absorption chillers must have the capability of operating at variable condenser water temperature without crystallization.

5-2.5.3 Use a throttling valve to modulate flow to the absorbent generator with chilled water temperature, as well as an automatic steam valve that reduces steam pressure and temperature, for energy efficient part load capacity control.

5-2.5.4 Consider using two-stage absorption refrigeration 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 section is intended for gas- and oil-fired low-temperature hot water boilers and low-pressure steam boilers that are used primarily for single building applications.

5-3.1 **Multiple Boiler Installations.** Provide adequate room, connections, piping, etc., in boiler installations where future expansion is likely. Determine the number and size of boilers to efficiently serve 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, consider adding an additional boiler or hot water heater sizes for the anticipated summer load.

5-3.2 **Feedwater Heating Systems.**

5-3.2.1 Provide heaters for the de-aeration of feedwater for all boiler installations with steam capacities in excess of 20,000 MBtuh (6,000kW). Evaluate the benefits for heaters for the de-aeration of feedwater for all boiler installations of 15,000 MBtuh (4,500 kW) to 20,000 MBtuh (6,000 kW) capacity where estimated makeup rates are 15 percent or more or where the plant serves a number of buildings. Installations using either hot lime-soda or hot lime plus hot sodium zeolite softeners to de-aerate treated water and condensate require no additional de-aeration.

5-3.2.2 Provide steel surge tanks for the storage of condensate. Install the surge tanks upstream 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. Size surge tanks for 20 minutes of condensate storage based on boiler steaming capacity.

5-3.2.3 Feedwater flow rate to the heater should equal the boiler demand. Size feedwater pumps 10 percent larger than the capacity calculated to allow for pump cooling requirements.

5-3.2.4 Install feedwater heaters above the boiler feed pump suction at a height sufficient to prevent flashing at the pump inlet at the design feedwater temperature. With a feedwater temperature of 212 degrees F (100 degrees C) and a back pressure on the feedwater heater of approximately 2 psi (14 kPa), the hydrostatic head on the feed pumps should be approximately 10 feet (3 meters). Where the boiler feed operates at temperatures above 212 degrees F (100 degrees C), increase the hydrostatic head in proportion to the increase in the vapor pressure of the liquid. Provide a bypass and isolation valves for each feedwater heater to permit operation of the boilers at times when the heater is being serviced.

5-3.3 **Combustion Equipment.** The installation of combustion equipment, including burners and draft fans, shall be in accordance with ASHRAE Handbooks, Underwriters Laboratory (UL), National Fire Protection Association (NFPA), and the recommendations of equipment manufacturers. Note that ASHRAE 15 prohibits open flame in machinery rooms where refrigerants are used.

5-3.3.1 **Gas Burners.** 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. Specify gas equipment for dual-fuel capability.

5-3.3.2 **Oil Burners.** The selection of oil burners will depend on the grade of the oil being burned, the size of installation, and the need for modulating control. For light oil, atomizing will be accomplished using oil pressure, air, or steam atomizing burners. For heavy oil, atomizing will be accomplished using air or steam atomizing burners.

5-3.3.3 **Stacks and Draft Requirements.** Heating installations will include either natural-draft chimneys or individual boiler ventilation fans with stub stacks. Where natural-draft stacks would be a hazard to aircraft or otherwise objectionable, use mechanical-draft fans discharging into short stub stacks.

5-3.4 **Fuel Selection and System Design.** Fuel selection and system design will be in accordance with the ASHRAE Handbooks, NFPA Standards, UFC 3-600-01 Fire Protection Engineering for Facilities, and AR 420-49.

5-3.5 **Auxiliaries.** Boiler plant auxiliaries should, in general, be electrically driven; however, whenever an uninterrupted supply of steam is essential, provide one of the boilers with steam-driven auxiliaries. Provide individual forced or induced-draft fans with each boiler unit. Provide necessary standby equipment to maintain essential operations.

5-3.6 **Flow Measurement.** Meter gas, oil steam, and hot water at the central plant (both supply and return) and at each building served (supply). Meter both the supply line and the return line of each storage tank.