UFC 3-410-01
28 July 2025
Change 1, 23 January 2026

UNIFIED FACILITIES CRITERIA (UFC)

HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS

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HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location
1	23 Jan 2026	Modified paragraph 1-8 UFC Supplement (UFS) 3-410-01; Added paragraph 2-3. General Ventilation Requirements which incorporates DOAS requirements; Replaced language in paragraph 2-4.2; Added paragraph 2-5.8 Exercise-Related Spaces; Added paragraph 2-8 Heating System Capacity; Deleted paragraph Fan Coil Applications for Ventilation Air from chapter 2; Added paragraph 2-14 Radiant Heating and Cooling Systems; Added paragraph 2-15 Air Handling Unit Dampers; Added paragraph 2-22 Moisture and Mold Mitigation; Modified paragraphs 2-4.1, 2-4.2.1, 2-4.2.2, 2-4.3.4, 2-4.3.5, 2-4.3.7, 2-5.1, 2-5.4, 2-5.5, 2-5.6, 2-5.11, 2-5.12, 2-5.13.1, 2-5.14.2, 2-7, 2-10, 2-11, 2-12.3, 2-12.4, 2-13, 2-16, 2-19.1, 2-21.2, 3-2.5.1, 3-2.6.3, 3-2.9.2, 3-2.10.2, 3-2.11.1, and 3-2.11.4.

This UFC supersedes UFC 3-410-01, dated 01 July 2013.

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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, its territories, and possessions 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 most 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 Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

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

- Whole Building Design Guide website https://www.wbdg.org/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*, 01 July 2013, and all subsequent changes.

1-2 PURPOSE AND SCOPE.

This UFC provides requirements and guidance in the design of heating, ventilating, and air-conditioning (HVAC) systems, together with the criteria for selecting HVAC materials and equipment.

1-3 APPLICABILITY.

This UFC follows the same applicability as UFC 1-200-01, paragraph 1-3, with no exceptions.

Additions, alterations, renovations, or repairs, except for one-for-one equipment replacements, to a HVAC system must conform to that required for a new HVAC system without requiring the entire existing HVAC system to comply with all the requirements of this UFC. One-for-one equipment replacements must meet the product requirements in paragraph Energy Efficient Products and the equipment efficiency requirements in the currently adopted version of ASHRAE 90.1 or IECC, whichever is applicable, referenced in paragraph Energy Standards in UFC 1-200-02. Do not execute additions, alterations, or repairs that cause an existing HVAC system to become unsafe, hazardous, or overloaded or result in new maintenance or control deficiencies in the existing systems.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, physical security, cybersecurity, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 MECHANICAL CONSENSUS STANDARD

Use the International Mechanical Code (IMC), including all published errata, as the DoD code for Heating, Ventilating, and Air-Conditioning, except as modified by this UFC, other UFC, and FC. When interpreting the IMC, the advisory provisions must be considered mandatory. Interpret the word “should” and “shall” as “must.”

1-6 ENVIRONMENTAL SEVERITY AND HUMID LOCATIONS.

In corrosive and humid environments, provide design detailing, and use materials, systems, components, and coatings that are durable and minimize the need for preventative and corrective maintenance over the expected service life of the component or system. UFC 1-200-01, section titled “Corrosion Prone Locations” identifies corrosive environments and humid locations requiring special attention. UFC 1-200-01, section titled “Requirements for Corrosion Prone Locations” provides examples of necessary actions. To determine Environmental Severity Classifications (ESC) for specific project locations refer to UFC 1-200-01 Appendix titled “ESC for DoD Locations”.

1-7 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-8 UFC SUPPLEMENT (UFS) 3-410-01.

\1 UFS 3-410-01 contains supplemental information including best practices, design documentation requirements, weather data access instructions, and Army policy information regarding district and islanded energy plants. UFS 3-410-01 is located under Related Materials on the UFC 3-410-01 webpage: https://www.wbdg.org/dod/ufc/ufc-3-410-01. **/1/**

CHAPTER 2 GENERAL DESIGN REQUIREMENTS

2-1 HVAC SYSTEM SELECTION.

Comply with UFC 1-200-02 which provides requirements that influence the selection and design of heating, cooling, and ventilation systems and major system components.

For Army projects, comply with *Evaluation of District and Islanded/Decentralized Utility Options with Life-Cycle Cost Analysis Guidance* in UFS 3-410-01 to determine which alternative is most life cycle cost effective.

2-2 DESIGN DOCUMENTATION REQUIREMENTS.

Comply with the design analysis and drawing requirements in the UFS 3-410-01.

2-3 \1\ GENERAL VENTILATION REQUIREMENTS /1/

\1 For ventilation air provided to occupied spaces cooled or heated for comfort, select and control HVAC systems and equipment to manage the humidity of the ventilation air through the full range of part-load conditions to minimize moisture and mold potential in the building and maintain space humidity at indoor design conditions. Provide continuous dehumidification for ventilation air when commercial HVAC or dedicated outdoor air systems (DOAS) equipment is available with continuous dehumidification capabilities. When such equipment is not commercially available, use all other available means to maintain space humidity requirements. Zone-level HVAC equipment, such as fan-coil units and heat pumps, must not be used for conditioning ventilation loads.

[C] GENERAL VENTILATION REQUIREMENTS

Ventilation air can be a major contributor to mold and moisture problems for DoD facilities. Humidity in ventilation air must be appropriately managed to mitigate the potential for such problems. DOAS may be required by the following paragraphs. In some applications, a DOAS may be necessary for dehumidification even when not prescribed. When available commercial equipment has limited dehumidification capabilities, consider other strategies such as airflow reduction, energy recovery to pre-treat ventilation air, or space dehumidifiers.

2-3.1 [Air Force Projects Only] DOAS Applicability

A DOAS is the only allowed method for providing dehumidification of ventilation air (outdoor air) when the sum of all ventilation air into facility is greater than 1000 cfm (472 lps) and the 1% occurrence humidity ratio is above the humidity ratio at the indoor design condition for comfort cooling. The requirement for DOAS applies only to ventilation of non-industrial, occupied spaces that are heated or cooled for comfort.

2-3.2 [Army and Navy Projects Only] DOAS Applicability

A DOAS must be used to supply ventilation air to occupied spaces that are heated or cooled for comfort when all the following conditions exist:

- 1% occurrence humidity ratio for the outdoor air is greater than 60°F dewpoint.
- The total ventilation air for the building is 1000 CFM (470 lps) or greater.
- The building and space cooling systems are incapable of continuously dehumidifying to maintain space humidity at indoor design conditions during part-load conditions of 25% design capacity or higher.

[C] [ARMY AND NAVY PROJECTS ONLY] DOAS APPLICABILITY

Cooling systems with limited dehumidification capability due to available coil performance, fan or refrigerant circuit cycling, or available control turn-down limitations are inappropriate for providing outdoor air to buildings or spaces when dehumidification is necessary. Use of such systems to provide outdoor air results in mold, moisture, and thermal comfort problems in buildings. This problem commonly exists with space-level or zone-level systems such as packaged terminal air conditioners, mini-split systems, VRF terminals, or fan-coil units. The problem also commonly exists in some central systems packaged or split-system direct-expansion or heat pump air handling units without turn-down controls such as refrigerant or hot-gas bypass or variable speed compressors. Refer to paragraph 2-4 for requirement to perform psychrometric analysis to demonstrate compliance.

2-3.3 DOAS Requirements

When DOAS is required by the applicability sections above, systems must be selected and designed as follows:

- Cooling coil must be selected to meet outdoor air sensible and latent loads.
- Cooling coil must be selected to maintain a coil leaving air temperature no greater than 55.0 °F (12.8 °C) at design conditions.
- When included, preheat and reheat coils must be selected to maintain required space thermal comfort conditions at design conditions.
- DOAS must distribute airflow directly to zones through an independent and dedicated duct system. Exception: DOAS may distribute airflow directly to single zone HVAC units such as fan coil units and chilled beams provided that such units provide required ventilation for all occupied hours.
- DOAS air inlets and outlets must deliver airflow quantities equal to or greater than 20 cfm (10 lps) through each device to allow for proper system balancing.

- DOAS must be provided with energy recovery devices in accordance with ASHRAE Standard 90.1.
- System controls must monitor the DOAS cooling coil leaving air temperature and unit discharge air temperature.
- An alarm must be initiated upon detection of cooling coil leaving air temperature being equal to or greater than 5° F (3 °C) above setpoint temperature at the Operator workstation (OWS) or at DOAS control interface for construction without an OWS. **/1/**

[C] DOAS Requirements

Refer to Best Practices in UFS 3-410-01 for further information regarding DOAS and handling outdoor airflows lower than the threshold of balancing accuracy.Space latent load may be included in cooling coil sizing where conditions warrant.

Zone level HVAC units, such as fan coils, typically cycle fans to meet loads, which can lead to required ventilation rates not being met when spaces are occupied, and fans are off. To meet the ventilation requirements, the single zone HVAC unit fans may need to run continuously. For these scenarios, ensure proper fan operation and energy is designed and accounted for in life cycle cost and energy modeling calculations.

2-4 HEATING AND COOLING LOAD CALCULATIONS.

Heating and cooling system design loads for the purpose of sizing systems, appliances and equipment must be determined in accordance with the following requirements.

Perform a psychrometric analysis documenting that the system meets design criteria. The analysis must provide calculations of system cooling load, energy/mass transfer through conditioning equipment and fans, and a system schematic indicating state point dry-bulb and wet-bulb temperatures (or humidity ratios) of outdoor air, mixed air, supply air, and return airflow streams. The system must provide the capability to condition ventilation air and maintain space relative humidity over the full range of cooling load.

2-4.1 Load Calculations.

Heating and cooling system design loads must be determined in accordance with the calculation procedures described in the ASHRAE Standard 183 unless otherwise specified herein.

\1 When a safety factor is included in heating equipment sizing, provide no more than a 1.15 safety factor. **/1/**

2-4.2 Outdoor Design Conditions.

\1 Use engineering weather data from the 14th Weather Squadron website (https://climate.af.mil/) for outdoor design conditions for project sites with available data. When data is not available for a project site on the 14th Weather Squadron website, contact 14th Weather Squadron to request site data. If data is not received within 7 calendar days, data from ASHRAE Fundamentals Handbook may be used. Refer to the UFS 3-410-01 for 14th Weather Squadron website access and site data request instructions. **/1/**

2-4.2.1 Spaces Conditioned for Comfort Cooling.

Size equipment and all system components to maintain and control indoor design conditions at each of the following: (1) the 1.0% occurrence dry-bulb and the corresponding mean coincident wet-bulb (MCWB) temperature, and (2) the 1.0% occurrence humidity ratio and corresponding mean coincident dry-bulb (MCDB) temperature.

\1 For evaporative equipment, size equipment and all system components to maintain and control indoor design conditions at the 1.0% occurrence wet-bulb temperature and corresponding MCDB. **/1/**

[C] \1\ Spaces Conditioned for Comfort Cooling.

The intention of the requirement for sizing at both the 1% occurrence dry-bulb and the 1% occurrence humidity ratio is to have the designer consider all conditions seen by equipment when selecting equipment. For example, cooling coil sizing could be driven by the humidity ratio day, while fans could be sized based on the dry bulb condition. **/1/**

2-4.2.2 Spaces Conditioned for Specialized Technical Requirements.

\1 Spaces with specialized technical requirements must be determined by the Authority Having Jurisdiction (AHJ) and real property owner. **/1/** Size equipment and all system components to maintain and control indoor design conditions at each of the following: (1) the 0.4% occurrence dry-bulb temperature and the corresponding MCWB temperature, and (2) the 1.0% occurrence humidity ratio and corresponding MCDB.

[C] \1\ Spaces Conditioned for Specialized Technical Requirements.

Where Facilities Requirements Documents (FRDs) require sizing of equipment at different conditions, those values may be used. **/1/**

2-4.2.3 Spaces Conditioned for Comfort Heating.

Size equipment and all system components to maintain and control indoor design conditions at the 99% occurrence dry-bulb temperature.

2-4.2.4 Open Cooling Towers and Wet, Closed-Circuit Cooling Towers.

For sizing open cooling towers and wet closed-circuit cooling towers, add 5 °F (3 °C) to the 1.0 percent outdoor wet-bulb temperature.

2-4.2.5 Condensers, Condensing units, and Dry, Closed-Circuit Cooling

Towers.

For sizing condensers and condensing units, add 5°F (3°C) to the outdoor dry-bulb temperature design condition.

2-4.3 Indoor Design Conditions.

Indoor cooling and heating conditions are determined as follows unless specified in a facility type UFC or FC or as approved by the AHJ and the real property owner. The design must take into account all heat gains including the latent heat gain in the space.

[C] Indoor Design Conditions

Indoor design conditions given are for the purposes of equipment and system design and sizing to ensure adequate capacity. The conditions given are not intended to restrict operational control settings. As an example: setting the space temperature control setpoint to 75 F would not be a deviation from this UFC. Controls setpoints, occupant adjustments, and other control parameters, where not defined in UFC 3-410-02 should be coordinated with the end user.

The conditions given are to limit the potential for excessive oversizing of equipment because outdoor air conditions exceed design conditions only 1% of the time resulting in partial loading of equipment for a significant portion of the year. This can be exacerbated by raising or lowering the design conditions. Oversizing can result in poor control of humidity, excessive equipment cycling, and result in a decrease in energy efficiency. For typical occupant activities, clothing levels, and space air distribution velocities (such as in administrative or educational spaces) and when operational controls (thermostats) are set appropriately, equipment sized at the indoor design conditions given will meet ASHRAE Standard 55 most of the time. Approval may be sought from the AHJ and real property owner when space usage may necessitate different indoor design conditions. Consideration for approval of different conditions should include assurance that the design has mitigated the issues associated with equipment oversizing and energy efficiency.

2-4.3.1 Spaces Conditioned for Comfort Cooling.

78.0° F (25.6 °C) dry-bulb / 57.9° F (14.4 °C) dewpoint / 50-percent relative humidity.

2-4.3.2 Spaces Conditioned for Comfort Cooling Using Evaporative Equipment.

Provide conditions meeting ASHRAE Standard 55.

2-4.3.3 Spaces Conditioned for Comfort Heating.

68°F (20°C) dry-bulb.

Provide humidification as needed to maintain indoor humidity above 30%. Space relative humidity is permitted to be lower than 30 percent for up to 40 occupied hours per year. Coordinate with the architect to design the building envelope to prevent condensation in the wall/roof systems during the time humidification is in operation. Include in the design analysis a dew point analysis profile (ASHRAE Fundamentals) for winter design conditions, showing condensation boundaries. The dew point analysis must consider the effect of air movement into the walls for buildings under positive pressurization relative to the outdoors.

2-4.3.4 Spaces Conditioned for Heating - High to Moderate \1\ Activity Working Area /1/.

55°F (12.8°C) dry-bulb. Examples of these facilities include areas in maintenance shops where engines are rebuilt and aircraft shops where instrumentation is repaired, warehouses areas where there are forklift loading operations, and aircraft hangars with high bay areas and limited amounts of people.

2-4.3.5 Spaces Conditioned for Heating - Freeze Protection.

\1 45°F (7.2°C) at the 99.6 percent occurrence **/1/** dry-bulb outdoor design temperature.

2-4.3.6 Spaces Which are Naturally or Mechanically Ventilated Only for Comfort.

Provide conditions meeting ASHRAE Standard 55.

[C] Spaces Which are Naturally or Mechanically Ventilated Only for Comfort

If mechanical cooling is provided as a back-up, the indoor conditions prescribed for spaces conditioned for comfort cooling and heating apply to sizing of the equipment and systems.

2-4.3.7 Spaces Conditioned for Process Cooling and Heating.

\1 Where spaces are designed to house a process that requires indoor design temperatures different from those indicated for comfort heating or comfort cooling, process **/1/** cooling and heating indoor design conditions are determined by the respective process requirements.

[C] \1\ Spaces Conditioned for Process Cooling and Heating.

Examples of building or space types where processes may merit consideration under 2-4.3.7 include: Laboratory spaces, Data Centers, Manufacturing, or Corrosion control. **/1/**

2-5 SPECIFIC FACILITY OR SPACE TYPE HVAC REQUIREMENTS.

2-5.1 Facility Air Conditioning Eligibility.

Facilities are eligible for air conditioning where facilities of similar structure and function in the local private sector are equipped with air conditioning. Air conditioning for comfort cooling is not allowed for the following facilities unless approved by the AHJ and real property owner. **\1\ /1/** Comfort conditioning is allowed in administrative areas of the following facilities.

- Motor vehicle storage garages
- Aircraft maintenance facilities & hangars
- Special areas requiring high ventilation rates (Examples: woodshops, paint booth) unless approved by the AHJ and real property owner
- Vehicle storage areas of crash and fire stations
- Boiler plants and rooms
- Greenhouses
- General Warehouses

2-5.2 Natural or Mechanical Ventilation Requirements.

In areas where mechanical or natural ventilation may be feasible, evaluate the use of these methods in lieu of other air conditioning methods to meet interior design conditions. Address ambient noise levels and the availability of prevailing winds in the evaluation. Include the effect of outdoor humidity levels when designing the mechanical ventilation systems.

[C] Natural or Mechanical Ventilation Requirements

In mild climates, where it is determined that air-conditioning is not necessary to maintain acceptable thermal conditions, natural ventilation, mechanical ventilation without mechanical cooling, or a combination may be used. Do not rely solely on natural ventilation or mechanical ventilation-only where these systems cannot meet required indoor conditions due to climate conditions. In such cases, mechanical cooling or heating will be necessary.

2-5.3 Intermittent Occupancy.

Facilities may experience different types of intermittent occupancy including:

- Long periods, sometimes months, of no occupancy such as when building users deploy.
- Daily extended periods of no or low occupancy such as barracks, housing, or some administrative facilities.

- Irregular or infrequent occupancy such as in reserve centers, chapels, auditoriums, theaters, or housing.

Design the systems and controls to avoid or mitigate negative impacts to the building and equipment due to the anticipated occupancy pattern of facilities. Design for humidity control during unoccupied periods to avoid building damage and mold.

2-5.4 Vestibules.

Vestibules must be heated to **\1** 45°F (7.2°C) and a maximum of 60°F (15.6°C) **/1/** to melt tracked-in snow in locations where conditions warrant. Provide heat for freeze protection when a wet-pipe sprinkler head is located in the vestibule. Otherwise, vestibules must not be heated or air conditioned.

[C] Vestibules

Consider the use of air curtains to limit infiltration. Consider pressurizing vestibules, from a source such as a DOAS, to limit outdoor air infiltration (while avoiding condensation and mold). Cooling vestibule spaces can lead to mold due to humid air infiltration and cool surfaces.

2-5.5 Closets, Storage, and Utility Rooms in Air-Conditioned Facilities.

Closets and unoccupied storage and utility rooms **\1** greater than 50 sf (4.6 sq. m) **/1/** must be ventilated by transfer air from adjacent conditioned spaces **\1** with return air sized at 50 cfm minimum or 0.5 cfm/sf, whichever is greater. **/1/** Provide space conditioning as necessary for stored materials.

2-5.6 Data Processing Centers and Server Rooms.

HVAC designs for data processing centers and server rooms must follow ASHRAE *Thermal Guidelines for Data Processing Environments* and DOE-FEMP “Best Practices Guide for Energy-Efficient Data Center Design” unless specific manufacturer’s guidance exceeds the criteria contained within. **\1** Space temperature and humidity requirements must be in accordance with ANSI/TIA-569. **/1/**

2-5.7 Laboratories.

The design of HVAC systems must provide control over space temperature conditions including contaminants and fume control appropriate to the space function. **\1** Where toxic substances are handled in laboratories, exhaust **/1/** systems must be provided with fume hoods to remove toxic substances as near to the source of the fumes as practical. Hood and system design must follow the recommendations of the following manual from the American Conference of Government Industrial Hygienists (ACGIH): *ACGIH Industrial Ventilation: A Manual of Recommended Practice for Design*. Where laboratories are required to be under a negative pressure relative to other areas in the facility, coordinate with the architect to locate these spaces in the interior to prevent negative pressure induced infiltration of outdoor air into exterior wall cavities. Medical labs must meet the requirements of UFC 4-510-01.

2-5.8 \1\ Exercise-Related Spaces. /1/

\1 For any facility type containing exercise-related space types addressed in UFC 4-740-02, HVAC design for those spaces must comply both with this document and UFC 4-740-02. **/1/**

2-5.9 Aircraft Maintenance Shops.

Provide air conditioning for those functional areas where required for quality control of equipment, material, and task. Localized or spot air conditioning is allowed at individual workstations.

2-5.10 Aircraft Fire and Rescue and Fire Station.

Provide fire apparatus vehicle exhaust removal systems in all new, rehabilitated, or self-help Aircraft Fire and Rescue Station and Fire Stations. Projects must prevent exposure of fire fighters and contamination of living and sleeping areas to exhaust emissions. As required by NFPA 1500, such systems must permit the operation of the apparatus with the apparatus doors closed. Refer to UFC 4-730-10.

2-5.11 Laundries and Dry Cleaners.

For commercial laundries or dry cleaners or dedicated laundry spaces in facilities such as fitness centers, barracks, officer quarters, or lodging facilities, mechanical ventilation must be the primary method of heat dissipation. Evaporative cooling may be provided **\1\ /1/**. Spot air conditioning or general air conditioning must be provided to keep the temperature in the work areas from exceeding 85°F (29°C). Coil discharge temperatures used in spot cooling must be 50°F (10°C) dry-bulb maximum for maximum dehumidification. Provide a readily accessible clean-out in all dryer exhaust ducts. These requirements do not apply to small laundry areas within a facility such as in small residences or where there few cleaning machines present in a larger multi-use space.

[C] Laundries and Dry Cleaners

Refer to applicable Facilities Criteria (FC) for requirements in laundries in specific facility types; such requirements supersede UFC 3-410-01 laundry requirements.

2-5.12 Commercial Kitchen Ventilation.

Comply with UFC 3-600-01, NFPA 96, ASHRAE Standard 154, and IMC. In addition, comply with the following requirements:

- Localized air conditioning or general air conditioning must be provided to keep temperature in the work areas from exceeding 85°F (29°C) dry-bulb

(Example: near cooking equipment) if the main portion of the facility is air conditioned and the criteria for exhaust ventilation are met.

- Kitchen work areas, such as the kitchen and dish and pot/pan washing areas, indoor air (ASHRAE Standard 62.1 Class 2 Air) must not be recirculated to HVAC systems that serve any spaces other than the kitchen areas.
- Do not use evaporative coolers for kitchens in humid areas.
- Furnish make-up air for the range hood exhaust, tempered to within 10°F (5.5°C) of space temperature.
- If additional make-up air is required for kitchen exhausts, provide push-pull kitchen hoods with built-in heated make-up air supply. **\1** Assembly must be factory tested. **/1/**
- Dishwashing area exhaust ducts must be as short as possible with direct runs to exterior of building. Ductwork must be aluminum or stainless steel and have watertight joints and must have a drain line from the low point. Approximately 25 percent of the exhaust air must be exhausted from the ceiling level.
- When heat in kitchens rejected by refrigeration equipment exceeds 36,000 Btuh (10,551 W), heat recovery systems must be used unless not life cycle cost effective.
- The design must not allow recirculation of more than 75 percent of air (excluding hood exhausts) in the kitchen at any time.
- Portable and fixed recirculating, ventless, ductless cooking equipment or hoods listed and labeled in accordance with UL 710B are permitted without a separate NFPA 96 compliant hood and duct system.
- Electrically interlocked supply and exhaust air fans must be designed for at least 2-speed operation. Commercial kitchen Type I or Type II hoods for systems over 1000 CFM (470 lps) must be provided with variable speed and demand control for exhaust air. Provide control interlocks for supply and exhaust fans to ensure that the HVAC system air balance is maintained, and that the proper direction of airflow is maintained during normal operations.

[C] Commercial Kitchen Ventilation

HVAC systems serving only the kitchen area may recirculate air. Air is not allowed to return from a kitchen area back to a central HVAC system that serves other areas.

Paragraph 2-4.3 Indoor Design Conditions applies to kitchen areas; however, it is recognized that the temperature near cooking equipment may be higher than the rest of the space. As stated, air-conditioning must prevent any area of the kitchen from exceeding 85°F dry-bulb.

UL 710B cooking equipment is fully compliant with NFPA 96 and IMC Section 507 without separate hood and duct system when installed and operated in accordance with the listing and the manufacturer's instructions.

2-5.13 Vehicle Maintenance Facility Ventilation.

Ensure compliance with the ventilation requirements in UFC 3-600-01 and adopted codes and standards.

Vehicle maintenance areas include all spaces in which any repair and maintenance activity for a vehicle occurs and through which vehicles travel.

2-5.13.1 Vehicle Exhaust Systems.

Provide vehicle exhaust removal systems, for source capture of emissions from individual vehicles running in place, in all facilities where vehicles generate exhaust fumes and pollutants. Systems must prevent exposure of building occupants to exhaust emissions.

- Do not use underfloor vehicle exhaust systems.
- Provide one exhaust hose for each vehicle repair area or station unless an additional one is required by using service. Coordinate with the using real property owner to locate flexible hoses such that total length of flexible hose does not exceed 25 feet (7.6 m). Hoses must not interfere with maintenance operations or obstruct equipment such as traveling bridge cranes. Include hand or blast gate damper on each exhaust hose inlet.
- Provide one vehicle exhaust fan for each vehicle repair station and size each fan for one repair station unless specified otherwise by the real property owner or by using service standards.
- Do not discharge vehicle exhaust through building exterior walls. Discharge vehicle exhaust **\1** minimum of 3.5 ft (1.1 m) **/1/** above building roof level. Vehicle exhaust must be treated as Class 4 air in accordance with ASHRAE Standard 62.1 in maintaining required clearances from ventilation intake locations.
- Do not use polyvinyl chloride for exhaust ducts.
- Vehicle exhaust can contain flammable vapors and must not be combined with any other exhaust systems. Vehicle exhaust fans must be non-sparking.
- All exhaust system components must be compatible with the vehicle exhaust temperatures and exhaust requirements. Design exhaust transport velocities in the range of 3000 fpm (15 m/s) to 4500 fpm (23 m/s).
- Unless otherwise allowed by the real property owner or using service standards, design vehicle repair station exhaust inlets for 1400 cfm (660

lps) and 900 ºF (480 ºC). For vehicles with higher exhaust rate requirements, two exhaust lines may be combined.

2-5.13.2 General Exhaust System.

- The vehicle maintenance area must be maintained at a negative pressure relative to adjacent spaces with lower ASHRAE Standard 62.1 air classification.
- General building exhaust duct openings in vehicle maintenance areas must be located within 12 inches (0.3 m) of the floor and have multiple inlets to cover all parts of the floor area to remove vapor accumulations.
- Provide two stages of area exhaust in vehicle maintenance areas: standby and alarm stages. Provide a hand-off-automatic switch. In automatic position, the exhaust system must operate in standby and alarm stages as follows:
- Standby First Stage Exhaust must provide an exhaust rate of 0.75 cfm/ft2 (3.8 lps/m2) for the entire vehicle maintenance area when the building is occupied. This does not include exhaust provided by the vehicle exhaust systems.
- The Alarm Second Stage Exhaust must provide an exhaust rate of 1.50 cfm/ft2 (7.6 lps/m2) for the entire vehicle maintenance area when any carbon monoxide detector senses carbon monoxide levels exceeding 35 ppm or any nitrogen dioxide detector senses nitrogen dioxide levels exceeding 1 ppm in the breathing zone. This does not include exhaust provided by the vehicle exhaust system. Detectors must be listed in accordance with UL 2075 or equivalent and installed in accordance with their listing and manufacturers' instructions and recommendations. The gas detection system must activate visual and audible alarms. One carbon monoxide and nitrogen dioxide sensor are required for every eight vehicle repair bays. Sensors must be centrally located within the area they protect. The exhaust system must automatically revert to Standby First Stage Exhaust after the space is purged and contaminant levels drop below Alarm Second Stage Exhaust carbon monoxide and nitrogen dioxide setpoints.
- In the hand position, the exhaust system must operate in the Alarm Second Stage Exhaust mode (for comfort ventilation) except that visual and audible alarms must not activate.
- A manual on/off controlled, explosion proof, dedicated exhaust fan must be provided for any pit, below-grade work area, or subfloor work area used for lubrication, inspection, and automotive maintenance work, and exhaust inlets in these locations must be located 6 inches above maintenance pit floors. An exhaust inlet connected to a non-sparking exhaust fan must be provided for welding areas.

[C] General Exhaust System

Refer to NFPA standards such as NFPA 30A or NFPA 70 which include requirements for specific hazard classifications.

Sensors are indicated to be centrally located to ensure that sensors are spread throughout the facility and not collocated. Ensure sensor mounting heights are indicated based on gas density and intent to protect occupants. Carbon monoxide detectors should generally be in the breathing zone. Nitrogen dioxide detectors should be close to the floor and within maintenance pits.

2-5.13.3 Make-up Air System.

Single or multiple make-up air units with variable speed fans must be interlocked to track and supply make-up air for vehicle maintenance area general exhaust system and for each additional vehicle exhaust fan as each one is energized and deenergized. Make-up air units must provide 55 ºF (12.8 ºC) dry-bulb tempered make-up air when the building is occupied.

As each vehicle exhaust fan is energized, for up to 50% of the total number of vehicle exhaust fans, the control system must automatically control make-up air unit(s) to provide additional make-up air for each vehicle exhaust fan's airflow. Motorized outdoor air dampers at intake louvers must automatically open as required to provide the additional make-up air required if more than 50% of the vehicle exhaust fans are running.

2-5.14 Mechanical Rooms.

2-5.14.1 Mechanical Room Ventilation.

Where necessary to maintain temperatures within required operating conditions for equipment, mechanical rooms must be ventilated using outdoor 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. Provide the fan with 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°F (6°C) above the outdoor dry-bulb temperature when both equipment and ambient loads are at their maximum peaks. The high speed must be activated 10°F (6°C) below the maximum temperature at which the most sensitive item of equipment in the room can operate. The low speed must operate at 20°F (11°C) below that of the high speed.

Where a refrigerating system is housed within the mechanical room, the design of the room must comply with ASHRAE Standard 15.

2-5.14.2 Mechanical Room Air Conditioning.

With real property owner concurrence, air conditioning may be provided to prevent severe corrosion in areas with an Environmental Severity Classification (ESC) of C4 and C5 and in high humidity areas identified in ASHRAE Standard 90.1 as climate zones 0A, 1A, 2A, 3A, 3C, 4C and 5C. See UFC 1-200-01 for determination of ESC for project locations. In project locations as described above, seal the mechanical rooms from air leakage. Return air must not be taken from mechanical rooms by air handlers serving occupied spaces.

\1 With written real property owner concurrence, air conditioning may be provided when either of the following conditions exist:

- Ventilation is incapable of maintaining space within the environmental conditions required by equipment within spaces (such as for Variable Frequency Drives (VFD) or control panels)
- Ventilation would bring dust or dirt into space **/1/**

2-6 ECONOMIZER.

Use fixed dry-bulb temperature high-limit shutoff control for air-side economizers. The high-limit setpoint must be no higher than the setpoints described by ASHRAE Standard 90.1, Chapter 6 paragraph entitled "High-Limit Shutoff."

Where air-side economizers are used, except in packaged units with integral economizer control, provide separate dampers for economizer operation and for ventilation air requirements.

[C] ECONOMIZER

Consider the use of water-side economizers where cooling tower or other water is available for heat absorption and where conditions may make them more life cycle cost effective.

2-7 VARIABLE SPEED DRIVES.

2-7.1 Design

Design and construct systems to deliver maximum design flows with variable speed drives operating between 55 and 60 Hz, unless using motor and drives designed and rated for higher frequencies. **\1** For systems designed and rated for frequency greater than 65 Hz, provide redundant variable speed drive and eliminate bypass functions unless approved by the AHJ and real property owner. **/1/** Account for dirty filter loading and wet cooling coils in fan design and selection. **\1** Requirements of this section do not apply to electronically commutated motors (ECM). **/1/**

2-7.2 Balancing

Do not exceed maximum rated revolutions per minute and rated full load amperage during any mode of operation, including with loaded filters and wet cooling coils. Minimize throttling losses during system balancing. Replace or adjust fan drive sheaves to achieve system balance for belt-driven fans. Variable speed drives are permitted to exceed 60 Hz, **\1** up to maximum of 90 Hz, **/1/** only for motor and drive systems designed and rated for operation at higher frequencies. Variable speed drive must be capable of controlling to maximum and minimum flows with a drive operational range not less than 25 Hz. Pump impeller adjustment is required only when either the maximum or minimum flow cannot be maintained by the variable speed drive.

[C] Balancing

This requirement is for equipment using Variable Speed Drives only.

Running motors at frequencies higher than 60 Hz is allowed only for those designed and rated for such in order to manage risks such as rotor imbalance, increased vibration, increased heat generation, and premature failure of motor windings (from voltage spikes, electrical noise, and harmonics). **\1** For variable frequency drives equipped with bypass functions, motors will receive line voltage (60 Hz) when bypass is active. Consider this effect when selecting motors for frequencies higher than 60 Hz.

Variable frequency drives represent nonlinear loads in facilities which can cause harmonic distortion in the power systems. Where a significant number of VFD and other nonlinear loads will be in a facility, a harmonic distortion evaluation should be performed in accordance with UFC 3-520-01, and mitigation such as harmonic filters or other measures should be applied. This issue has occurred in the past causing damage and control failures and significant funding to correct and add filters post-construction.

Refer to Best Practices in UFS 3-410-01 for further considerations. **/1/**

2-8 \1\ HEATING SYSTEM CAPACITY. /1/

\1 When hydronic or steam heating systems include multiple heat generation appliances, such as boilers, heat pumps, or hot water generators, the systems must be capable of providing at least 65 percent of the maximum heating design load when any heat generation appliance is offline. The smallest heat generation appliance installed must be able to turn down sufficiently to maintain the minimum anticipated heating load. **/1/**

2-9 HUMIDIFICATION.

Use of district steam is prohibited as a humidification method. Use of wetted pad type or water spray type humidifiers is prohibited since these have the potential to inject Legionnaire bacillus as well as other pathogenic organisms into the air stream.

2-10 STEAM SYSTEMS.

Single-pipe systems must not be used for comfort heating. For safety purposes, low-pressure steam 15 psig (100 kPa gage) and below must be used where terminal equipment is installed in occupied areas. High- or medium-pressure above 15 psig (100 kPa gage) steam **\1** may be distributed to unit heaters for **/1/** 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.

\1\ /1/

2-11 GROUND-SOURCE HEAT PUMP SYSTEMS.

2-11.1 Sizing.

Refer to ASHRAE *HVAC Applications Handbook*, Chapter **\1** "Ground-Source Heat Pumps and Geothermal Energy", **/1/** for terminology applicable to this paragraph. This paragraph refers to the "building load loop" which is the water piping system that circulates water to the heat pump units (sometimes referred to as a "condenser loop"). In some systems, this is separated from the ground loop or ground water by a heat exchanger. In other systems, the building load loop and ground loop are the same piping system. The terms "ground loop" and "ground loop heat exchanger" (GLHX) are interchangeable. Design and size the ground loop to prevent the loss of capacity over time due to heating and cooling load imbalances.

2-11.1.1 Sizing Ground-Coupled Heat Pumps (GCHP) Systems.

For projects which are considering GCHP, field test the ground heat transfer capacity at the proposed well field site prior to design, **\1** at proposed depths determined after initial energy modeling and geoexchange calculations have been performed, such that test bores may be utilized in the final geoexchange installation. **/1/** Follow the requirements of ASHRAE *Geothermal Heating and Cooling: Design of Ground-Source Heat Pump Systems* and ANSI/CSA C448. If any conflict occurs between the two standards, use the more stringent requirements. Use computer design software to design nonresidential, commercial scale ground-coupled heat pump systems. Such software must consider the interaction with adjacent ground loops and minimum 10 years buildup of rejected heat in the soil. **\1\ /1/**

[C] Sizing Ground-Coupled Heat Pumps (GCHP) Systems

Professionals in the GCHP industry consider computer software geo-modeling data beyond 10 years as subjective, due to considerations not accounted for in the bulk of currently available software programs, such as water movement below the surface. If available geological data, test well data, or experience with other GCHP projects in the project area justify longer modeling periods, then the designer should consider running software models beyond the minimum required 10-year period to account for these known conditions.

\1 Heating and cooling load imbalances may lead to a loss in ground loop capacity over time. Extreme examples include cooling-only or heating-only systems. The ground loop design needs to take these imbalances into account. Some designs may need to include additional heating or cooling equipment in a hybrid system. Hybrid systems may also be necessary to handle peak loads when available wellfield capacity is limited due to such causes as limited space for the site, limited well depth, or soil conductivity conditions. **/1/**

2-11.1.2 Sizing Groundwater Heat Pumps (GWHP) Systems.

For projects which are considering GWHP, field test the ground water and geological conditions and characteristics for the proposed ground loop (well field) site prior to design. Follow the requirements of ASHRAE *Geothermal Heating and Cooling: Design of Ground-Source Heat Pump Systems* and ANSI/CSA C448. If any conflict occurs between the two standards, use the more stringent requirements. Nonresidential, commercial scale groundwater heat pump systems require the utilization of computer design software. Software model durations must be that recommended per current industry standards for open loop systems at the well field site based on ground water and geological conditions/characteristics in the specific project area.

2-11.1.3 Water Temperature Limits.

Design GCHP and GWHP system ground loops to prevent the maximum temperature of the source water serving the heat pump units from exceeding the manufacturer’s recommendations for entering water temperatures **\1** or 95°F (35°C), whichever is lower. **/1/** Design ground loops to prevent the minimum temperature of the source water from dropping below the manufacturer’s recommendations for entering water temperature **\1** or 35°F (1.7C), whichever is greater. **/1/** The controls system must monitor ground loop conditions to detect changes that impact system capacity.

[C] Water Temperature Limits

Predictions of ground loop conditions over time may be inaccurate. When the ground loop conditions change sufficiently to reduce capacity, the ground heat sink may need to be reconditioned, or the ground loop capacity supplemented using additional equipment. A monitoring system can support operating staff in making seasonal adjustments or planning for additional equipment.

2-11.2 Regulatory Requirements.

Comply with the local or state regulatory requirements for vertical wells.

[C] **\1** Regulatory Requirements

Regulatory requirements for vertical wells vary widely among States. Some regulations require partial or full grouting of the borehole. Confirm requirements with the real property owner and current state and federal regulations, as well as relevant building codes. **/1/**

2-11.3 Borehole Grouting.

Use thermally enhanced grout with thermal conductivity of 1.40 BTU/hr-ft-°F minimum. Consult ASHRAE Geothermal Heating and Cooling: Design of Ground-Source Heat Pump Systems.

2-11.4 Piping.

Provide a bypass line around each heat pump unit to facilitate flushing and purging the ground loop without subjecting the heat pump to residual construction debris. Provide test ports (sometimes referred to as "Pete's plugs") on the inlet and outlet to each heat pump unit, circulating pump and desuperheater, if incorporated. Provide isolation valves and valved tee connections for flushing and purging of the ground loop independently from the building load loop water system, **\1** sized using geoexchange simulation software. The ground loop flushing connections must also serve as connection points for temporary heating or cooling equipment to address future issues with the ground loop. **/1/**

The design and installation of the ground loop heat exchanger (GLHX) must be with future maintenance and troubleshooting in mind. **\1\ /1/** Use reverse return circuits, **\1** or size piping in circuits for approximately equal pressure drop in each circuit. **/1/** No more than 20 wells may be allowed on a single branch circuit. No more than 50% of the total number of wells for an entire system may be on a single branch circuit, except for systems with ten wells or less. Each individual supply and return loop length from the mechanical room or manifold must be within 15 percent of each other for hydronic balancing purposes. Each supply and return loop (field loop) from a GLHX manifold must have a shut-off valve and a balancing valve. Each manifold header must have both a visual temperature gauge and a visual pressure gauge. Each manifold header must have a shut-off valve on both the main supply and return header piping between all field loops and the building. All system manifolds must be within the building or in a vault with adequate room for equipment and device maintenance and replacement.

2-11.5 Ground Loop Circulating Pumps.

Use ground loop water circulating pumps with high efficiency or premium efficiency motors. Design them to operate near their peak of maximum efficiency.

2-11.6 Make-up Water.

Do not provide automatic water makeup in residential GCHP systems.

2-11.7 Freeze Protection.

In geographic areas with heating dominated climates, provide freeze protection when ground loop temperatures are expected to drop below 41°F (5°C). Minimize use of antifreeze. If antifreeze is necessary, use propylene glycol, keeping concentrations to a minimum. Coordinate glycol concentration with manufacturer to mitigate corrosion inhibitor degradation.

[C] \1\ Freeze Protection.

System calculations must consider the effects of glycol for pump and pipe sizing and coil heat transfer. **/1/**

2-11.8 Extended Range Equipment.

Ground coupled heat pumps must be purpose-built and designed to operate at the full range of entering water temperatures expected from the GLHX during the course of an entire annual season for residential systems and during the course of the entire 10-year software geo-modeling period for nonresidential commercial scale systems. The equipment manufacturer must demonstrate compliance by providing sufficient verifiable submittal data.

[C] Extended Range Equipment

Ground coupled heat pumps are water source heat pumps purpose built to operate at extended ranges of source entering water temperatures – temperatures that are common in systems with closed loop ground heat exchangers and beyond those of conventional boiler/chiller/cooling tower or open water well systems. Ensure that the heat pumps are constructed to operate in the conditions expected.

2-12 VARIABLE AIR VOLUME (VAV) COOLING.

2-12.1 VAV System Sizing.

Do not oversize the system. Do not add safety factors in the load calculations. Size all central air handling equipment and central plant equipment for “block” loads. Design for both peak and part-load conditions (Examples: minimal wall transmission load or low occupancy). Submit part-load design calculations. Verify proper fan operating characteristics throughout the range from the minimum to the maximum flow conditions that will be experienced.

2-12.2 VAV Direct Expansion System.

Direct expansion equipment must be specifically designed and manufactured for VAV applications.

2-12.3 VAV System Controls.

Do not use discharge dampers or inlet vanes on VAV air handler for air volume modulation. Provide fan speed control air volume modulation. Provide airflow monitoring stations, **\1** located with manufacturer requirements for installation (upstream/downstream straight duct) considered, for monitoring of ventilation airflow. **/1/** Provide a duct access door at the inlet to the sensor for periodic inspection and cleaning. For systems using a dedicated outdoor air handler for ventilation air directly connected to a VAV air handler, provide controls to ensure ventilation air requirements are maintained over all load conditions. Provide protection against over pressurization of the supply duct system. Locate the static pressure sensor for modulating fan capacity in a straight run of ductwork and as described in ASHRAE Standard 90.1 paragraph in Chapter 6 entitled "VAV Static Pressure Sensor Location." **\1** Final location of the static pressure sensors is to be determined during testing, adjusting, and balancing activities. **/1/** Provide static pressure reset based on zone requirements in accordance with ASHRAE Standard 90.1 paragraph in Chapter 6 entitled "VAV Set-Point Reset."

Use pressure independent terminal units. Primary air dampers must be installed for all series fan-powered VAV boxes, regardless of the type of fan speed control utilized (3-speed fan switch or solid-state speed control). Specify the ability to monitor VAV box hot water control valve position (if provided with hot water coils), control damper position, primary airflow, flow sensor pressure differential, and box leaving supply air temperature. Specify the integral mounting of communication ports for the VAV box digital controllers to the room zone temperature sensor. When occupied/unoccupied modes of control are required of the VAV system, specify remote momentary override switch mounted integral to the room zone temperature sensors to permit non-standard schedule operation during unoccupied modes.

[C] \1\ VAV System Controls

Airflow monitoring stations are required for monitoring ventilation airflow. They may be used for control of ventilation airflow, but such use is not required. Building differential pressure may also be used for ventilation control. **/1/**

2-12.4 VAV System Duct Design.

Use either the equal friction method or static regain method to design ducts. Primary air connections to VAV terminals must always be made with a rigid duct to avoid high turbulence in the proximity of the VAV terminal flow sensor. Design the primary air duct connections to the VAV terminals with a straight duct section of at least 4 duct diameters (more if required by specific manufacturers). Reducer and increaser duct fittings installed immediately upstream of the VAV terminal connection collars are prohibited. If the branch duct size is other than the VAV terminal connection collar size, install the reducer or increaser fitting upstream of the straight duct section. If a section of flexible duct, or a flexible connection, is **\1** necessary **/1/** for vibration control, limit the length to no more than 6 inches (150 mm), and ensure that **\1** minimum straight duct length is maintained **/1/** upstream of the VAV box collar connection/flow sensor.

[C] \1\ VAV System Duct Design.

Refer to ASHRAE Handbooks for best practice. **/1/**

2-12.5 Fan-Powered VAV Terminal Noise.

When fan-powered VAV terminal boxes are used, perform an acoustic analysis to ensure designs are within acceptable noise criteria levels. Provide attenuation as required. Acoustical duct liner is not permitted for attenuation.

2-12.6 VAV Terminal Maintenance Accommodations.

When installing VAV terminals at heights more than 12 feet (3.6 m) above finished floors, special maintenance accommodations are necessary:

- Do not use fan-powered VAV boxes in such locations, since there are many serviceable components involved.
- When direct digital controls (DDC) are installed, specify the location of the DDC digital controller to facilitate ease of access.
- Ensure floor area likely to remain clear of permanent or semi-permanent equipment is available below the VAV boxes to facilitate the means of access (Example: scaffolding).

2-13 VARIABLE REFRIGERANT FLOW (VRF) SYSTEMS.

Use of VRF systems requires real property owner approval.

\1\ /1/

[C] VARIABLE REFRIGERANT FLOW (VRF) SYSTEMS

Owner approval is particularly important for VRF systems because their complexity can introduce operational, maintenance and cybersecurity challenges that are not necessarily experienced by traditional HVAC systems. For example: a higher level of training and expertise required to repair the system; differences in capability to operate the system in a degraded or manual mode; safety and operational considerations of running refrigerant lines through occupied spaces.

2-13.1 VRF System Controls Requirements.

Comply with UFC 3-410-02 for open control system requirements.

2-13.2 VRF System Refrigerants.

Comply with ASHRAE Standard 15 and IMC safety requirements pertaining to leakage to rooms and spaces. Calculations must be performed in accordance with ASHRAE Standard 15 and IMC and must be provided to demonstrate these requirements are met. When refrigerant lines traverse through sleeping quarters, such as in dormitories, alert facilities, or fire stations, install refrigerant detectors 6 inches (150 mm) above the finished floor to activate an alarm system, including occupant notification, when detecting refrigerant.

2-13.3 VRF System Competition.

The design must not preclude competition between vendors. Since VRF systems from different manufacturers require different mechanical designs, provide a design with necessary design allowances to permit multiple manufacturers to meet the design.

Instead of requiring a specific VRF piping design, indicate where piping may be installed. Edit project specifications and requirements to include contractor design drawings as pre-construction drawing submittals. These drawings must document the details of the VRF design, including but not limited to piping layout.

2-13.4 VRF System Piping.

Designs must require that the system be configured and installed strictly in accordance with the manufacturer's installation requirement. VRF systems piping/tubing must have all brazed connections that meet ASME B31.5 requirements and the manufacturer's installation requirements. The list of fittings and joints that are prohibited include but are not limited to the following: push-on fittings, extruded fittings, flare fittings, press-connect fittings, mechanical joints, and groove joints. The VRF system must be pressure-tested and vacuum-tested. Include and require refrigerant line vibration isolation at all connections to motorized equipment, including but not limited to the refrigerant line connections at each fan coil unit.

2-13.5 VRF System Life-Cycle Costs.

When performing life cycle cost analysis for VRF systems include any additional costs associated with use of factory-trained technicians in the maintenance costs.

2-14 \1\ RADIANT HEATING AND COOLING SYSTEMS. /1/

\1 Where radiant heating or cooling systems are implemented, design surface temperatures such that they are always above space dew point. For radiant systems serving occupied spaces, ensure compliance with ASHRAE 55 using operative temperature determined using ASHRAE 55 Appendix C and mean radiant temperature (MRT) of the surfaces reflecting the design equipment selections. **/1/**

2-15 \1\ AIR HANDLING UNIT DAMPERS. /1/

\1 Provide parallel blade dampers for two-position, on/off control. Provide opposed blade dampers for modulating applications. **/1/**

2-16 REDUNDANT SYSTEMS.

When a system failure would result in unusually high repair costs, or replacement of process equipment, or when activities are disrupted that are mission critical, the designer **\1** may provide redundant HVAC systems if approved by the AHJ and real property owner. No approval **/1/** is required where redundant HVAC systems are specified by other applicable criteria.

[C] \1\ REDUNDANT SYSTEMS

Where appropriate, consider providing redundancy for air handling systems via fan arrays with additional fans in the array. Consider providing an additional redundant VFD for motors on fans or pumps serving critical applications. **/1/**

2-17 CORROSION.

Provide corrosion resistant coatings or materials for any exterior HVAC equipment and equipment handling outdoor air. This includes any coils exposed to outdoor air. Coatings must be applied by the manufacturer. Any reduction in heat transfer due to coil coatings must be taken into account when selecting equipment. Use upgraded materials/coatings in humid locations or project locations with Environmental Severity Classifications (ESC) of C3 thru C5. Humid locations are those in ASHRAE climate zones 0A, 1A, 2A, 3A, 3C, 4C and 5C (as identified in ASHRAE Standard 90.1).

[C] CORROSION

Implementation examples include using stainless steel, fiberglass, or ceramic in lieu of galvanized steel for cooling towers or aluminum in lieu of steel for exhaust fans.

2-18 EXTERIOR EQUIPMENT.

Locate HVAC appliances and equipment indoors whenever possible. Roof-mounting appliances or equipment is prohibited, except for air outlet and inlet terminals, unless approved by the AHJ and real property owner. In areas subject to extreme weather events with wind speeds over 115 miles/hour (185 km/hour) where locating appliances or equipment outside is unavoidable, locate appliances and equipment on the leeward side of the facility.

[C] EXTERIOR EQUIPMENT

Exterior and roof-mounted appliances and equipment are problematic in extreme weather events such as tornados, hurricanes, and typhoons. Roof-mounted equipment creates roof construction and maintenance problems. Approval may be sought from the AHJ and real property owner when locating appliances and equipment on the roof is unavoidable. Consideration for approval should include anticipated extreme weather risks, wind speeds, and appropriate mitigation for high winds, potential roof leaks, and roof warranty issues. The design must address safe maintenance access and ability to remove or replace equipment.

2-19 SOUND AND VIBRATION CONTROL.

2-19.1 Sound and Vibration Design and Construction.

Comply with UFC 3-450-01. Design HVAC systems to maintain noise levels below those recommended for the proposed occupancy in accordance with the most stringent requirements of UFC 3-101-01, UFC 3-450-01, the ASHRAE *Applications Handbook*, and SMACNA guidelines. Preferably, locate sound sensitive rooms away from air handlers and mechanical equipment. **\1** Internal acoustical duct liner is not allowed; external duct lagging is allowed. **/1/** Use double wall acoustic duct and duct silencers or sound attenuators where sound attenuation cannot be accomplished by other methods. Increase the outside duct dimensions as required to maintain adequate internal cross sections. Double wall acoustic duct and duct silencers or sound attenuators must include a barrier material between the air and any fibrous dissipative fill material.

Use UFC 3-450-01 and either ASHRAE *Applications Handbook,* Chapter "Noise and Vibration Control" or manufacturers recommendations for vibration isolation design requirements.

[C] Sound and Vibration Design and Construction

The primary risk of acoustic duct liner is mold growth. While many duct liner materials are inorganic, dust and dirt can be trapped in the lining material over time which can serve as food for some molds. Sealants and backing materials may also have organic compounds. While liner material can be treated with anti-microbial agents which can work for several years, duct cleaning and retreatment may be necessary to maintain effectiveness. When microbial food sources are present and duct conditions exceed around 80% relative humidity (Example: supply ducts conveying air for cooling), the conditions for mold growth exist. While this risk is reduced in return, exhaust, or relief ducts where the conditions are not as extreme, building operation or system failures could lead to such conditions.

In addition, fiberglass material particles can break loose from the duct and be introduced to space breathing zones. These are irritating particles and can be especially problematic for certain people or occupancies.

In the event duct silencers/sound attenuators or double-wall duct must be used, fibrous fill material must be isolated from the air stream. This will reduce the effectiveness of the devices/ducts.

Refer to Best Practices in UFS 3-410-01 for possible sound and vibration control strategies.

2-19.2 Sound Testing.

Conduct sound measurement when determined necessary by the designer or real property owner. Sound measurement must be conducted after air and water balancing has been completed.

[C] Sound Testing

Consider requiring sound measurements for the following spaces:

- Spaces sharing a common barrier with each appliance, boiler, furnace, equipment, machinery, or mechanical room.
- Spaces such as auditoriums, conference rooms, classrooms, or theaters where intelligibility is a critical function of the space.

- Representative occupied spaces that are served by each type of HVAC primary air system.

2-20 DUCTWORK AIR LEAKAGE TESTING (DALT).

All new pressurized duct systems (connected to a fan) must be leak tested following the procedures in UFGS 23 05 93. Specify the DALT requirements using the Ductwork Construction and Leakage Testing Schedule indicated in UFGS 23 05 93.

[C] DUCTWORK AIR LEAKAGE TESTING (DALT)

The “All new duct systems..” does not refer to all ductwork within all systems. The intent is that every individual system is leak tested. DALT within each system, or portion thereof, will be performed in accordance with UFGS 23 05 93 including sampling requirements.

The requirement for DALT applies only to duct systems that are pressurized (connected to a fan). Transfer air ducts without a fan, for example, do not require DALT.

2-21 HVAC SYSTEM TESTING, ADJUSTING, AND BALANCING (TAB).

TAB all HVAC systems following the procedures in UFGS 23 05 93 and do not exceed nameplate motor amperage in normal operating conditions.

2-21.1 Balancing Valves.

Provide balancing valves for hydronic balance. The designer must specify the size of the balancing valves required in each application, cognizant of the required differential pressure requirements in the pipe systems. A balancing device is required in coil bypasses only when coil drops are more than 2 feet w.g. (6 kPa). Do not use valves that combine multiple functions such as isolation, balancing, and check valve (example: triple duty valves). Provide separate valves for each of these functions.

[C] 2-21.1 Balancing Valves

Triple-duty valves combine shut-off or isolation, balancing, and check valve functions to save space in a hydronic system. After the balance is set and marked on the valve and the valve is closed for isolation of equipment, it is difficult to return the balance to the original setting based on the marking. Calibrated measuring equipment would be required to return to the original balance. This is problematic for ongoing operation. Combining isolation and balancing functions in a valve must be avoided.

2-21.2 Flow Balancing Valves.

Provide flow balancing valves in the discharges of all closed-circuit pumps and at all hydronic equipment, units, and coils. **\1** For closed-circuit pumps controlled by variable speed drive with a flow measurement device installed in the discharge piping, pump discharge flow balancing valve may be omitted. **/1/** Provide flow balancing valves in branch piping serving ten or more terminal balancing valves. For pipe sizes larger than 3 inches (80 mm), a venturi flowmeter combined with a butterfly valve must be specified. Install all flow control balancing valves with no less than the manufacturer's recommendations for straight lengths of pipe up and downstream of the device. Designers must select the proper size flow control-balancing valve for each application to ensure the devices are not oversized; valves must be selected using the median flow rating indicated in the manufacturer's published performance data.

2-21.3 Flow Limiting Valves.

Flow limiting valves include valves that maintain a flow rate regardless of upstream pressure, such as automatic flow limiting valves, autoflow balancing valves, or pressure-independent control valves. Flow limiting valves are permitted only with approval from the real property owner. Systems that use flow limiting valves must include a separate flow measurement device (such as orifice, venturi, or calibrated balancing valve) to verify the flow rate by measurement. The testing, adjusting, and balancing report must include flow measurement using the separate flow measurement device. Use of pressure drop across coils or heat exchangers for this purpose is not allowed as the sole measurement method. When autoflow balancing valves are used, include a side-stream sub-micron filtration system, and provide a flushing bypass upstream of the valves. Automatic flow balancing valves and automatic flow limiting values must not be used in conjunction with 2-way modulating control valves.

[C] Flow Limiting Valves.

Automatic flow limiting valves (AFLV), Automatic Balancing Valves, and Pressure-Independent Control Valves (PICV) limit flow rate through the device regardless of upstream pressure, if the pressure is within a specific range. These are used to make system balancing less labor intensive and provide stable flow conditions in a system.

AFLV cartridges are easy to mix up which can result in incorrect flow balance. Some manufacturers or models of these valves do not include a means for measuring flow rate to verify that the valve is working correctly (unlike calibrated balancing valves or use of separate measurement devices). Typically, verification of flow for such devices just confirms the pressure drop across the valve is within an acceptable range and the flow rate setting is assumed to be the correct actual flow. Additional devices need to be included in the system to measure flow for verification.

Autoflow balancing valves are prone to clogging due to poor water quality. The side-stream filter is meant to mitigate issues with clogging.

When using flow limiting valves in circuits that use a 2-way modulating control valve, the operational control range at the 2-way control valve is reduced. As the modulating control valve strokes to reduce flow, the flow valve may operate to maintain the flow constant until the modulating control valve has enough control authority to overcome the flow valve. This reduces the amount of range in the modulating control valve to control flow.

Real property owner approval is needed due to the potential problems that balance the benefits of their use, including consideration for maintaining the side-stream filter(s).

2-21.4 Balancing Dampers.

Except for primary VAV supply ductwork from air handling unit outlet to air terminal unit inlet, provide manual volume dampers for all main and branch ducts; these include all supply, return, and exhaust ducts. Do not use splitter dampers or air extractors for air balancing. Provide opposed blade manual balancing damper for outdoor air.

2-22 \1\ MOISTURE AND MOLD MITIGATION. /1/

\1 Refer to ASHRAE Handbook HVAC Applications, Chapter ‘Avoiding Moisture and Mold Problems’, and ASHRAE Handbook Fundamentals, Chapter ‘Moisture Management in Buildings’ for considerations for avoiding or mitigating moisture and mold problems in buildings. Coordinate with the architectural design to ensure appropriate building envelope designs and appropriate envelope and mechanical system insulation, barriers, and sealing, including within or adjacent to interstitial spaces. Select and control heating, ventilating, and air-conditioning systems and equipment to manage humidity for both ventilation air and interior spaces through the full range of part-load conditions, to minimize moisture and mold potential. Consider temperatures at surfaces exposed to humid conditions. Consider whether air-conditioning of interstitial spaces is appropriate. **/1/**

[C] \1\ MOISTURE AND MOLD MITIGATION

Moisture and mold problems are a serious problem for DoD facilities, typically caused by leaky building envelopes, condensation forming within interstitial spaces, including on cold piping or ductwork, and poor mechanical system dehumidification capabilities, particularly at part-load conditions. **/1/**

2-23 COMMISSIONING REQUIREMENTS.

Commissioning must be provided as required by UFC 1-200-02.

[C] Commissioning Requirements

UFC 1-200-02 references industry standards or codes for commissioning requirements. Commissioning is integrated into each service’s design, construction, and quality management differently based on varying business process and practices. Refer to service-specific guidance for commissioning. UFGS 01 91 00.15 and associated discipline commissioning specification sections, when the appropriate tailoring is applied, provide the general construction requirements for commissioning contractors.

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CHAPTER 3 IMC MODIFICATIONS

(Note: The IMC-2024 version is used solely to associate requirements with chapter and paragraph numbers. Refer to UFC 1-200-01 for currently adopted version of ICC codes.)

Chapter 4 of this UFC modifies IMC for mechanical-specific design and construction requirements and is organized by the chapter of IMC that each section modifies. The format, including English and metric unit references, does not follow the UFC format, but instead follows the format established in the IMC, to the extent possible. The IMC section modifications are one of four actions, according to the following legend:

[Addition] – Add new section or sentences, including section number, not shown in IMC.

[Deletion] - Delete referenced IMC section or noted portion.

[Replacement] – Delete referenced IMC section or noted portion and replace it with the narrative shown.

[Supplement] – Add narrative shown as a supplement to the narrative in the referenced section of IMC.

3-1 GENERAL SUBSTITUTIONS.

- All references to “approved” materials must be materials allowed by the applicable Unified Facilities Guide Specification (UFGS).
- All references in the International Mechanical Code to the International Building Code must be considered to be references to UFC 1-200-01.
- All references in the International Mechanical Code to the International Fuel Gas Code must be considered to be references to NFPA 54 and NFPA 58.
- All references in the International Mechanical Code to the International Plumbing Code must be considered to be references to UFC 3-420-01.
- All references in the International Mechanical Code to the International Energy Conservation Code must be considered to be references to UFC 1-200-02.
- All references in the International Mechanical Code to the International Fire Code must be considered to be references to UFC 3-600-01
- All references in the International Mechanical Code to NFPA 70 must be considered to be references to UFC 3-501-01.

3-2 IMC MODIFICATION PARAGRAPHS.

3-2.1 IMC CHAPTER 1 SCOPE AND ADMINISTRATION [Deletion]

Delete Chapter 1 in its entirety. The administrative requirements are covered by the applicable Federal Acquisition Regulations and by the authority granted to the Contracting Officer in administering the contract.

3-2.2 IMC CHAPTER 2 DEFINITIONS.

Section 202 – General Definitions [Replacement]

Replace the following definitions published in Chapter 2 with the following definitions:

APPROVED. Acceptable to the code official or other authority having jurisdiction. "Approved" materials must be materials allowed by the applicable Unified Facilities Guide Specification (UFGS).

CODE OFFICIAL. The Code Official is the authority having jurisdiction as described in UFC 1-200-01.

Section 202 – General Definitions [Additions]

Add the following definitions to Chapter 2:

DEDICATED OUTDOOR AIR SYSTEM (DOAS). Dedicated equipment used to condition all the outdoor air brought into a building (or area) for ventilation, separate from HVAC systems that handle space heating and cooling loads. The air provided from a DOAS is 100% outdoor air.

OWNER OR OWNER'S REPRESENTATIVE. For Government-owned facilities, the Contracting Officer assigned by the Government to administer the construction contract. For leased facilities, the lessor of the facility.

PERMIT HOLDER. The contractor accomplishing the project.

REAL PROPERTY OWNER. The real property owner is the organization that accepts the property after construction by signing the DD Form 1354.

[C] 3-2.2 IMC CHAPTER 2 DEFINITIONS

For the Air Force, it is recommended that the Real Property Owner contact the Air Force Civil Engineer Center Reach-Back Center when considering approvals in accordance with this UFC. This is particularly important when considering approvals for VRF systems, carbon dioxide (CO2) ventilation control, return air plenums, or emerging ground source heat pump system technologies.

3-2.3 IMC CHAPTER 3 GENERAL REGULATIONS.

3-2.3.1 Section 304 – Installation.

304.1 – General [Addition]

Insert after the last sentence of Section 304.1:

"Supports and connections for all equipment mounted on a roof must be detailed by the structural engineer. Ductwork must be connected to equipment with flexible connections and supported to ensure proper alignment."

3-2.3.2 Section 306 – Access and Service Space.

306.5 – Equipment and appliances on roof or elevated structures [Addition]

Insert after the last sentence of Section 306.5:

"The means to access the equipment must be shown on the mechanical drawings."

3-2.3.3 Section 307 Condensate Disposal.

307.2.1 - Condensate Disposal [Addition]

Insert after the last sentence of Section 307.2.1:

"Terminate condensate drain lines in accordance with the IMC and local direction. To preclude moisture carryover, coil face velocities must not exceed 550 feet (167.6 meters) per minute."

3-2.3.4 Section 309 Temperature Control [Replacement].

Replace Section 309 with the following:

"Section 309

HVAC CONTROL

309.1 HVAC Control. Comply with UFC 3-410-02, UFC 4-010-01, and UFC 4-010-06. This includes controls provided as part of a packaged unit. Provide a control system with at least the minimum points as indicated in Table 4-1 DDC Minimum Points List."

Table 3-1 DDC Minimum Points List

Hot Water Heating System	VAV System
• Hot water pump status • Hot water pump start/stop • Hot water supply temperature • Hot water return temperature • Hot water flow rate • Hot water mixing valve position • Differential pressure across pump • Boiler status • Boiler enable/disable • Boiler failure alarms • Heat exchanger inlet temperatures • Heat exchanger leaving temperatures • Hot water pump speed • Condensate return pump status	• Airflow rate of each VAV box (primary) • VAV box fan control start/stop • VAV box fan status • VAV box damper position • Discharge air temperature at each VAV box • VAV box hot water valve position • Electric reheat (on/off and number of stages) • Zone temperature • Effective zone temperature setpoint (heating/cooling) incorporating setpoint adjustment.

Table 3-1 DDC Minimum Points List

Chilled Water System	Air Distribution System
• Chiller enable/disable • Chiller status • Chiller failure alarms • Entering and leaving water temperatures at each chiller • Chilled water flow rates for each chiller • Secondary loop chilled water flow rate • Chilled water supply and return temperatures for the central plant • Water temperature in the common piping of the primary/secondary loop • Chilled water system differential pressure at central chilled water plant • Chilled water system differential pressured used for control of secondary pumps • Primary chilled water pump start/stop • Primary chilled water pump status • Cooling tower fan status (high-low-off) • Cooling tower fans - Adjustable frequency drive functions and alarms • Condenser water supply and return temperature • Cooling tower bypass valve position • Variable speed pump drive frequency • Heat exchanger inlet temperatures • Heat exchanger outlet temperatures	• Supply air temperature • Supply air dewpoint temperature • Supply air static pressure • Supply airflow rate • Outdoor air temperature • Outdoor air relative humidity • Calculated outdoor air dewpoint temperatures • Return air temperature • Mixed air temperature • Discharge temperature from each heat transfer device • Filter status • Supply/return/exhaust damper positions • Outdoor air damper positions • Chilled water valve positions • Hot water valve positions • Electric heater status (on/off and number of stages energized or % power) • Freezestat status • Smoke detector status • Supply/return fan start/stop • Supply/return fan speed • Supply/return fan status • Supply/return fan alarm • Exhaust fan status • Outdoor air fan status • Energy recovery wheel rotation status • Smoke damper status
General Building Systems	
• Building electrical meter* • Building water meter* • Building natural gas meter* • Building steam meter* • HVAC equipment shutdown switch status	*For Navy projects: Metering for the building (facility wide consumption) needs to be coordinated with the RFP and base utilities. DDC monitoring, accumulating, and totalizing is not required for utilities connected to the AMI metering system or if the base has a base wide utilities smart metering system. Sub metering for the different utilities must be connected to the DDC as required per the RFP and ASHRAE Standard 90.1 requirements.

3-2.3.5 Section 312 Heating and Cooling Load Calculations [Deletion].

Delete Section 312 in its entirety.

3-2.4 IMC CHAPTER 4 VENTILATION.

3-2.4.1 Section 401 General.

Replace Section 401.1 through 401.4 and 401.6 content with the following:

401.1- Scope [Replacement]

“Comply with ASHRAE Standard 62.1 or, for residential buildings, ASHRAE Standard 62.2. Use the “ventilation rate procedure” in calculating minimum outdoor air requirements. For Army and Air Force projects, use of CO2 sensors for ventilation control is prohibited unless approved by AHJ and the real property owner.

Maintain toilets, lockers, and utility closets at a negative pressure relative to adjacent areas during occupied periods by exhausting air to the outdoors and transferring air from these adjacent areas.

For industrial applications not covered by ASHRAE Standard 62.1 comply with UFC 3-410-04.”

[C] Section 401 General

CO2-based demand control ventilation is prohibited due to both a lack of clear standards for setting CO2 concentration setpoints and due to issues with initial and ongoing calibration. While CO2 sensor technology has been improved over time, including addition of automated calibration features, a study found no significant studies of field application and was not able to obtain certifications or accuracy or calibration intervals from manufacturers. When seeking approval to use CO2 sensors, ensure that the justification adequately addresses determination of CO2 concentration setpoints and calibration issues. If approval is sought, it is recommended that CO2 sensors include automatic recalibration features that use background CO2 readings to adjust calibration on an ongoing basis. It is also recommended to address the extent to which accuracy of the sensors impact ventilation rates. The prohibition does not preclude the use of CO2 sensors solely for monitoring purposes.

The Indoor Air Quality Procedure (IAQP) in ASHRAE Standard 62.1 may be used but ventilation rates must not be reduced below those determined in accordance with the Ventilation Rate Procedure. ASHRAE Standard 62.1 refers to this as the “Combined IQA Procedure and Ventilation Rate Procedure.” The IAQP may be used to determine the additional ventilation air or air cleaning required to achieve concentration limits for contaminants of concern. The IAQP may be used when there are known contaminants of concern either internal or exterior to the building. Contaminant emission rates and target concentrations must be well-supported by industry guidance and standards.

3-2.4.2 Section 402 Natural Ventilation [Replacement].

Replace all Section 402 content with the following:

“Natural ventilation systems are to be in accordance with ASHRAE Standard 62.1 or, for residential buildings, ASHRAE Standard 62.2.”

3-2.4.3 Section 403 Mechanical Ventilation [Replacement].

Replace all Section 403 content with the following:

“Mechanical ventilation systems are to be in accordance with facility criteria or ASHRAE Standard 62.1 or, for residential buildings, ASHRAE Standard 62.2. Design air distribution systems for central HVAC systems to maintain a slightly positive pressure (0.02” w.g. (5 Pa)) relative to the outdoors within the area served to reduce or eliminate infiltration unless there is a valid need to maintain a negative pressure in that area. Maintain pressure relationships in each pressure zone (defined by full height interior walls, fire/smoke barriers, and external walls) and not exclusively calculated for the building as a whole. Specify airflow rates to maintain the required pressure relationships that take into account the balancing tolerances in UFGS 23 05 93. Ensure that duct design incorporates all features necessary to accommodate testing, adjusting, and balancing (TAB).

Provide airflow measuring devices to directly measure outdoor airflow in all systems. Provide straight duct length upstream and downstream of airflow measuring devices equal to or greater than the manufacturer’s recommendations. Filter all outdoor air entering airflow measuring devices.”

[C] Section 403 Mechanical Ventilation [Replacement]

Building area pressurization relative to the outdoors is a mitigation strategy to limit infiltration of air contaminants into the building. Refer to ASHRAE Standard 62.1 for information regarding outdoor air quality and contaminants of concern. Care must be taken with building envelope design and construction in cold climate zones where air exfiltration increases potential for condensation in envelope assemblies.

Airflow tolerances and pressurization: The balancing tolerances in UFGS 23 05 93 are +/-5% as the default. Depending on how close the outdoor and exhaust/relief air sums are, there is a possibility that, after balancing to tolerance, the outdoor air is lower than the exhaust/relief air. The designer should consider this possibility when establishing the design flow rates to avoid negatively pressurizing or inadequately positively pressurizing the building. The designer should review TAB reports to ensure that the building is pressurized in accordance with the design intent.

3-2.4.4 Section 406 Ventilation of Uninhabited Spaces.

406.1 - General [Addition]

Insert after the last sentence of Section 406.1:

"All air-conditioned facilities with uninhabited spaces outside the air/moisture barrier must be designed to achieve maximum natural ventilation of the uninhabited space."

3-2.4.5 Section 407 "Ambulatory Care Facilities and Group I-2 Occupancy".

407.1 - General [Replacement]

Replace Section 407 with the following:

"Ambulatory Care Facilities and Group I-2 occupancy must be designed in accordance with UFC 4-510-01."

3-2.5 IMC CHAPTER 5 EXHAUST SYSTEMS.

3-2.5.1 Section 501 General.

501.1 – General [Addition]

Insert after the last sentence of Section 501.1:

"Use this chapter and UFC 3-410-04. If any conflict occurs between this chapter and UFC 3-410-04, the requirements of UFC 3-410-04 take precedence. The medical gases must meet the requirements in UFC 4-510-01. Mechanical ventilation and exhaust systems for flammable, hazardous, grease laden, or toxic vapors, gases or fumes must follow the applicable NFPA standards."

501.7 - Roof fans [Addition]

"501.7 Roof Fans. Roof exhaust fans should be avoided due to maintenance access restrictions and roof leak potential. If provided, use direct drive fan motors with speed controllers to reduce maintenance requirements **\1** and provide with hinged curb kit for means for access from below roof. **/1/** Provide airtight seal between the fan frame and the wood nailer of the roof curb. The duct of ducted roof fans must extend through the fan curb to a flanged and sealed termination at the top of the curb."

3-2.5.2 Section 502 Required Systems.

502.3 - Battery-charging areas for powered industrial trucks and equipment [Addition]

Insert after the last sentence of Section 502.3:

"Mechanical ventilation systems are to be in accordance with UFC 3-410-04."

Section 502.4 – Stationary storage battery systems [Addition]

Insert after sentence of Section 502.4:

“Design stationary secondary battery installations and battery maintenance and repair facilities in accordance with UFC 3-410-04 and UFC 3-520-05.”

Section 502.5 - Ventilation of battery systems in cabinets [Addition]

Insert after sentence of Section 502.5:

“Valve-regulated lead-acid (VRLA) batteries installed in cabinets must be provided with ventilation in accordance with UFC 3-520-05 and UFC 3-410-04.”

Section 502.13 - Public garages [Replacement]

Replace Section 502.13 with the following:

“502.13 Public garages. Mechanical exhaust systems for public garages must be in accordance with the applicable provisions of NFPA 88A.”

Section 502.19 - Indoor firing ranges [Replacement]

Replace Section 502.19 with the following:

“502.19 Indoor firing ranges. Mechanical ventilation systems must be provided in accordance with UFC 4-179-02 Small Arms Range Criteria. Additionally, for Air Force, mechanical ventilation systems must also be provided in accordance with FC 4-179-03F Air Force Indoor Small Arms Firing Range.”

3-2.5.3 Section 505 Domestic Cooking Exhaust Equipment.

505.3 – Exhaust ducts [Deletion]

Delete Exception 1 in its entirety. Range hoods must discharge to the outdoors.

3-2.5.4 Section 507 Commercial Kitchen Hoods.

507.3 – Type II hoods [Replacement]

Replace Section 507.3 with the following:

“507.3 Type II hoods. Type II hoods must be installed above dishwashers and appliances that produce heat or moisture and do not produce grease or smoke as a result of the cooking process, except where the heat and moisture loads from such appliances are incorporated into the HVAC system design or into the design of a separate removal system. Type II hoods must be installed above all appliances that produce products of combustion and do not produce grease or smoke as a result of the cooking process. Spaces containing cooking appliances that do not require Type II hoods must be ventilated in accordance with Section 403.3 and ASHRAE Standard 62.1. If any conflict occurs between ASHRAE Standard 62.1 and Section 403.3, the requirements of ASHRAE Standard 62.1 take precedence. For the purpose of determining the floor area required to be exhausted, each individual appliance that is not required to be installed under a Type II hood must be considered as occupying not less than 100 ft2 (9.3 m2). Such additional square footage must be provided with exhaust at a rate of 0.70 cfm/ft2 (.00356 m3/(s-m2)).”

3-2.5.5 Section 509 Hazardous Exhaust Systems.

509.2.1 – Lumber yards and woodworking facilities [Replacement]

Replace Section 509.2.1 with the following:

“509.2.1 Lumber yards and woodworking facilities. Equipment or machinery located inside buildings at lumber yards and woodworking facilities which generates or emits combustible dust must be provided with an approved dust-collection and exhaust system. The systems must be in conformance with section 509 and UFC 3-600-01. Woodworking exhaust systems must be designed in accordance with UFC 3-410-04.”

3-2.5.6 Section 512 Smoke Control Systems.

512.1 – Scope and purpose [Addition]

Insert before the first sentence of Section 512.1:

“Use Section 512 and UFC 3-600-01. If any conflict occurs between Section 512 and UFC 3-600-01, the requirements of UFC 3-600-01 take precedence.”

3-2.6 IMC CHAPTER 6 DUCT SYSTEMS.

3-2.6.1 Section 601 General.

601.2 - Air movement in egress elements [Addition]

Insert after the last sentence of Section 601.2:

“Corridors in all new construction must conform to NFPA 90A.”

3-2.6.2 Section 602 Plenums.

602.1 - General [Addition]

Insert after the last sentence of Section 602.1:

“Return plenums are prohibited unless approved by AHJ and the real property owner. All returns must be ducted from each occupied space to the associated air handling equipment for all HVAC systems. UFC 3-600-01 does not override this requirement.”

[C] Section 602 Plenums

Return plenums are prohibited for a combination of reasons. When not designed correctly, achieving space airflow balances can be problematic and space-to-space pressure can be excessive. If construction of the building envelope or separation from hazardous spaces is not tight enough and if the plenum is negatively pressurized relative to the outdoors or hazardous areas, infiltration can be excessive and cause health and indoor air quality issues. Electrical systems must be plenum rated to limit potential for smoke generation into the HVAC system. Because velocities in return air systems are low, particulates can accumulate in the plenum which results in indoor air quality concerns. If approval is sought, ensure that all of these issues are addressed in the justification. Also ensure that there are no other hazardous materials or conditions that may exist within the plenum (example: in existing buildings, old fluorescent light ballasts may contain polychlorinated biphenyls (PCBs)).

3-2.6.3 Section 603 Duct Construction and Installation.

603.1 – General [Addition]

Construct all ductwork to meet SMACNA seal class A.

603.1.1 - Prohibited construction [Addition]

“Do not use the following types of duct construction:

- Sub-slab or intra-slab HVAC ducts.
- Plenum-type, sub-floor 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.”

603.3 – Duct classification [Replacement]

Replace the first sentence of Section 603.3:

“Construct all ductwork based on the maximum operating pressure of the duct and to no less than 1-inch w.g. (250 Pa) pressure class (½ inch w.g. (125 Pa) pressure class is not allowed).”

603.5 - Nonmetallic ducts [Replacement]

Replace Section 603.5 with the following:

"603.5 Nonmetallic ducts. Nonmetallic ducts must be constructed with Class 0 or Class 1 duct material and must comply with UL 181. Fiber or gypsum board ducts are prohibited."

603.6.1.1 - Duct length [Replacement]

Replace Section 603.6.1.1 with the following:

"603.6.1.1 Duct length. Flexible air ducts must not exceed 5 feet (1.5 m) in length. Limit bends and turns to 45 degrees. **\1** Provide sheet metal 90 degree elbow at diffuser connections, unless not possible due to physical space constraints." **/1/**

603.6.2.1 - Connector length [Replacement]

Replace Section 603.6.2.1 with the following:

"603.6.2.1 Connector length. Flexible air connectors must not exceed 5 feet (1.5 m) in length."

603.8 - Underground ducts [Replacement]

Replace Section 603.8 with the following:

"603.8 Underground ducts. The use of underground ducts for general comfort conditioning is prohibited, except for sub slab soil exhaust systems, per Section 512, which are allowed."

\1\ 603.18 – Registers, grilles, and diffusers [Addition]

Insert after the last sentence of Section 603.18:

"Design diffusers, registers and grilles for outlet noise criteria (NC) less than or equal to space design NC, a maximum air pressure drop of 0.10" at design airflow, and 1000 fpm maximum velocity.

Air diffusion performance index (ADPI) calculations, which use catalog throw performance at a terminal velocity of 50 fpm (T50) and the space characteristic length (L), may be provided in lieu of the selection criteria above. For diffusers, registers and grilles selected using ADPI calculations, NC must still comply with space design NC.

Refer to UFC 3-450-01 to assess impact of duct design on diffuser, register and grille performance." **/1/**

603.19 - Control Dampers [Addition]

"603.19 Control Dampers. Provide parallel blade dampers for two-position, on/off control. Provide opposed blade dampers for modulating applications.

3-2.6.4 Section 604 Insulation.

604.1 – General [Replacement]

Replace Section 604.1 with the following:

"604.1 General. Insulate all ventilation, supply, return, and exhaust air ducts in accordance with ASHRAE Standard 90.1 and the product and installation requirements of UFGS 23 07 00. Duct insulation must conform to the requirements of Sections 604.2 through 604.13 with the following exceptions. Spray polyurethane foam insulation, foam plastic insulation and internal duct insulation is prohibited. Duct insulation must be external, and duct board or internal duct liner is not allowed."

604.7 - Identification [Deletion]

Delete Item Number 4 in Section 604.7 in its entirety.

3-2.6.5 Section 605 Air Filters.

605.1 – General [Addition]

Insert after the last sentence of Section 605.1:

"Comply with ASHRAE Standard 62.1 requirements for filters and particulate matter removal. For non-industrial spaces that are conditioned for thermal comfort, provide filtration or air cleaning devices for both outdoor air and recirculated air with filters or devices having a MERV of not less than 13. Coordinate with the real property owner to determine whether pre-filters must be provided upstream of any outdoor air filters of MERV 11 or higher. Provide a filter upstream of all outdoor airflow monitoring stations to prevent dust/dirt build up that may clog the sensor."

[C] Section 605 Air Filters

ASHRAE recommends use of MERV 13 for filtration. Note that ASHRAE Standard 62.1 requires a minimum of MERV 11 filters upstream of wetted surfaces. Pre-filters (recommended minimum MERV 8) extend the life of MERV 13 filters by catching coarser particulates. MERV 8 filters are less expensive to replace than higher MERV filters. Consider sizing fans for a "dirty" filter condition to ensure adequate capacity to deliver design airflow as the filter becomes loaded.

3-2.6.6 Section 606 SMOKE DETECTION SYSTEMS CONTROL [Replacement].

Replace Section 606 with the following: "Comply with UFC 3-600-01."

3-2.6.7 Section 607 DUCT AND TRANSFER OPENINGS [Replacement].

Replace Section 607 with the following: "Comply with UFC 3-600-01."

3-2.7 IMC CHAPTER 8 CHIMNEYS & VENTS.

3-2.7.1 Section 801 General.

801.2 – General [Addition]

Insert after the last sentence of Section 801.2:

"See ASHRAE HVAC Systems and Equipment Chapter entitled "Chimney, Vent, and Fireplace Systems" for general chimney and vent design information and Table 2 for estimates of typical chimney flow rates. Where natural-draft stacks would be a hazard to aircraft or otherwise objectionable, use mechanical-draft fans discharging into short stub stacks. Equipment spaces equipped with natural draft stacks must not be designed to operate at a negative pressure.

3-2.8 IMC CHAPTER 9 SPECIFIC APPLIANCES, FIREPLACES AND SOLID FUEL-BURNING EQUIPMENT.

3-2.8.1 Section 901 General.

901.5 – Combustion equipment [Addition]

"The installation of combustion equipment, including burners and draft fans, must be in accordance with ASHRAE Handbooks, Underwriters Laboratory (UL), National Fire Protection Association (NFPA), and the recommendations of equipment manufacturers. Direct-fired heaters must not be used in areas subject to hazardous concentrations of flammable gas, vapors, or dust. Locate fuel burning equipment, such as packaged slab-mounted HVAC units away from windows, doors, or outdoor air intakes. Gravity flow warm air furnaces must not be used.

D901.5.1 Gas burners. All gas-fired equipment must be equipped with a burner, which can be readily converted to burn an alternate fuel.

D901.5.2 Oil burners. The selection of oil burners must depend on the grade of the oil being burned, the size of installation, and the need for modulating control. For light oil, atomizing must be accomplished using oil pressure, air, or steam atomizing burners. For heavy oil, atomizing must be accomplished using air or steam atomizing burners."

3-2.8.2 Section 908 Cooling Towers, Evaporative Condensers and Fluid Coolers.

908.5 – Water supply [Addition]

Insert after the last sentence of Section 908.5:

"Provide automatic blowdown and chemical feed provisions to all cooling towers to maintain cleanliness."

3-2.8.3 Section 912 Infrared Radiant Heaters.

912.4 – Installation [Addition]

"912.4 Installation. When using non-condensing gas infrared heaters, the length of the exhaust flue must be minimized. To minimize condensation, run the flue horizontally with a slight pitch down from the heater to a sidewall exit. Heaters must be properly braced where excessive movement, such as by wind through an open hangar bay door, may cause separation of radiant pipe sections and rupture of gas connections. Provide ducted combustion air intake through roof or exterior wall. Direct vents for condensing type infrared heaters to carry water vapor and exhaust out of the building."

3-2.8.4 Section 918 Forced-Air Warm-Air Furnaces.

918.2.1 – Application [Addition]

"Design air-to-air heat pumps with auxiliary heat when necessary in cold climates. Auxiliary electric heat must be limited to the capacity needed to supplement the heat pump."

3-2.8.5 Section 928 Evaporative Cooling Equipment [Replacement].

Replace Section 928 with the following:

"Section 928

EVAPORATIVE COOLING EQUIPMENT

928.1 Applications. Evaporative cooling must only 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.

928.2 Design. Evaporative cooling equipment must:

- Be installed in accordance with the manufacturer's instructions.
- Be installed on level platforms in accordance with Section 304.10.
- Be sized and provided with potable water backflow protection in accordance with UFC 3-420-01.

3-2.9 IMC CHAPTER 10 BOILERS, WATER HEATERS AND PRESSURE VESSELS.

3-2.9.1 Section 1001 General.

1001.1 - Scope [Replacement]

Replace Section 1001.1 with the following:

"1001.1 Scope. This chapter governs the installation, alteration and repair of boilers, water heaters and pressure vessels. Use Chapter 10 and UFC 3-430-11 for boilers. If any conflict occurs between Chapter 10 and the above UFC, the requirements of the UFC take precedence."

3-2.9.2 Section 1004 Boilers.

\1\ /1/1004.3 - Working clearance [Addition]

Insert after the last sentence of Section 1004.3:

"Clearance around boilers must be per ANSI/NB23, National Board Inspection Code, Part 1, Sections 2 and 3, each with respective paragraphs entitled "Clearances."

3-2.9.3 Sections 1005 Boiler Connections.

1005.3 Feedwater systems [Addition]

"Provide heaters for the de-aeration of feedwater for all boiler installations with steam capacities in excess of 20,000 MBtuh (6,000kW). 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. Provide a bypass and isolation valves for each feedwater heater to permit operation of the boilers at times when the heater is being serviced.

1005.3.1 Feedwater pump requirements. Feedwater flow rate to the heater must equal the boiler demand. Size feedwater pumps 10 percent larger than the capacity calculated to allow for pump cooling requirements. Boiler feedwater pumps discharge pressure must conform with National Board Inspection Code, Part 1, Section 2, paragraph entitled "Pumps."

1005.3.2 Surge tanks. 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.

1005.4 Boiler auxiliaries [Addition]

"Boiler plant auxiliaries must 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."

3-2.9.4 Section 1009 Hot Water Boiler Expansion Tank.

1009.2 - Closed-type expansion tanks [Addition]

Insert after the last sentence of Section 1009.2:

"Use diaphragm type expansion tanks. Size the expansion tank according to the latest edition of the ASHRAE Systems and Equipment Handbook. Indicate the acceptance volume, nominal dimensions, configuration (Examples: horizontal or vertical) and pre-charge air pressure."

3-2.9.5 Replacement - Section 1009.3 "Open-Type Expansion Tanks".

1009.3 – Open-type expansion tanks [Replacement]

Replace Section 1009.3 with the following:

"Open-type expansion tanks are prohibited."

3-2.10 IMC CHAPTER 11 REFRIGERATION.

3-2.10.1 Section 1101 General.

1101.1.3 - ASHRAE Standard 15 Application Clarifications. [Addition]

"Apply sections 1101.1.3.1 through 1101.1.3.5 when using ASHRAE Standard 15 paragraphs "Connected Spaces via Ducted Air Distribution Systems" and "Connected Spaces via Mechanical Ventilation."

1101.1.3.1 Definitions. For application of section 1101.3, the following terms are defined for calculation of total Effective Dispersal Volume (V_{eff}):

- Primary dispersal volume: The V_{eff} volume for a release considering only the sum of:
  - Volume calculated per paragraph "Room Volume."
  - Volume calculated per paragraph "Connected Spaces via Natural Ventilation."
- Secondary dispersal volume(s): Additional volume(s) added to the primary dispersal volume using paragraphs "Connected Spaces via Ducted Air Distribution Systems" and "Connected Spaces via Mechanical Ventilation."

1101.1.3.2 Combining "Connected Spaces via Natural Ventilation" with "Connected Spaces via Ducted Air Distribution System" and "Connected Spaces via Mechanical Ventilation." The use of mechanical methods of moving air (mechanical ventilation and air distribution systems) affects natural ventilation by potentially creating a mono-directional airflow through an opening that was previously calculated for natural ventilation. In such cases, the natural ventilation calculations no longer apply, and the volumes must be analyzed using "Connected Spaces via Ducted Air Distribution System" and "Connected Spaces via Mechanical Ventilation" requirements.

1101.1.3.3 Connected Spaces via Ducted Air Distribution

Spaces, as well as plenums and supply and return ductwork, may be considered connected and the volume in the plenums and supply and return ductwork may be included when the flow rates for the room (the space used for Room Volume calculation) are calculated in accordance with ASHRAE Standard 15 paragraph "Mechanical Ventilation" as modified in paragraph 1101.1.4. If the room supply airflow is not greater than the required airflow, theses spaces, plenums, and ducts are not considered connected and not to be used in the V_{eff} calculations. The duct system intakes within such spaces must be within 1 foot (0.3 m) of the floor.

In addition, for spaces to be considered connected, the air distribution system must distribute air between spaces such as recirculating systems (example: return airflows to supply air duct system) or transfer air systems. Space connection by ductwork is insufficient justification to determine that spaces are connected. (Example: systems that are 100% outdoor air or exhaust air do not recirculate, and the spaces are not considered connected.) This does not preclude including plenum and supply and return ductwork when the airflow rates meet the above requirements.

1101.1.3.4 Connected Spaces via Mechanical Ventilation

When calculating the required mechanical ventilation flow rate in ASHRAE Standard 15 paragraph "Mechanical Ventilation," the Effective Dispersal Volume Charge (EDVC) used in the numerator of the equation 7-11 must use only the primary dispersal volume. For Class 1 refrigerants, the Refrigeration Concentration Limit (RCL) must be used in place of the Lower Flammability Limit (LFL). In equation 7.10 for Class 1 refrigerants, a value of 1 (one) must be used for the LFL conversion factor (C_{LFL}).

When calculating the V_{eff} for use in calculation the EDVC, secondary dispersal volumes must only be included if both of the following are true:

- The airflow volume requirement in paragraph "Mechanical Ventilation" is met, as modified above.
- The mechanical ventilation system transfers air from the primary dispersal volume to the secondary dispersal volume(s). Connection by ductwork is insufficient justification to determine that spaces are connected.

1101.1.3.5 Special Occupancies

For spaces in which occupants are regularly expected to sleep in a bed, room volume calculated must be limited to the use of a height of 3 feet (0.9 m) above the floor. Use of "Connected Spaces via Ducted Air Distribution" and "Connected Spaces via Mechanical Ventilation" requires that duct system intakes be within 1 foot (0.3 m) of the floor.

For spaces in which occupants are regularly expected to sleep on or within 1 foot (0.3 m) of the floor (such as in Child Development Centers), room volume calculations must be limited to a height of 1 foot (0.3 m) above the floor. Use of "Connected Spaces via

Ducted Air Distribution" and "Connected Spaces via Mechanical Ventilation" requires that duct system intakes be within 1 foot (0.3 m) of the floor."

[C] Section 1101 General

The intent of refrigerant safety requirements is to ensure that concentrations remain below allowable thresholds to reduce the risks of occupant exposure to toxins, asphyxiation, and fire when there is a leak. Most refrigerants are denser than air and will generally fill a room from the bottom up. ASHRAE Standard 15 calculations allow the use of an entire room volume for concentration calculations which poses a higher risk for occupants that are sleeping at lower room elevation and would be unaware of the refrigerant leak. The methods for determining volumes using connected spaces via ducted air distribution systems or mechanical ventilation lack clarity relative to the calculations. The requirements provided herein are intended to clarify the application of these methods and to increase protection of occupants.

1101.10 – Refrigerant oil [Addition].

"1101.10 Refrigerant oil. Compressors operating in parallel must have the normal oil level at the same elevation for all machines and the crankcases of these compressors must 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 must 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 must return refrigerant gas and oil from the evaporator to the compressor during operation of the system and must 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."

3-2.10.2 Section 1102 System Requirements.

1102.4 - Absorption refrigeration [Addition]

"Use 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. Absorption chillers must have the capability of operating at variable condenser water temperature without crystallization. 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. Use two-stage absorption refrigeration whenever high-pressure steam or high-temperature water is available."

1102.5 - Reciprocating refrigeration [Addition]

"For reciprocating chillers over 10 tons (35 kW), use capacity control that reduces the power requirement as the load varies. Individual reciprocating machines must not exceed 200 tons (700 kW) 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 must not exceed 400 tons (1400 kW). A single packaged unit must not contain more than eight compressors."

1102.6 - Centrifugal refrigeration [Addition]

"When a two-stage centrifugal compressor is selected, a refrigerant intercooler must also be required. For low-temperature applications, where compressors with four or more stages are used, two-stage intercoolers must be used. Use capacity control methods to reduce energy consumption as the load is reduced to minimize life cycle costs. Use variable frequency drives; inlet vane control is not allowed."

1102.7 - Multiple chillers [Addition]

"Where multiple chillers are specified, provide **\1** a condenser pump (when condenser pumps are necessary) and a chilled water pump **/1/** for each chiller. Provide piping and valve configuration that allows each chiller to operate with any condenser water pump and primary pump. Except for the criteria listed herein, the number of chillers specified must be optimized in life cycle cost analyses. In multiple chillers installations the sequence of operation must ensure that the chillers are loaded and unloaded optimally for best performance and energy efficiency. Provide connection and communication between the chiller panels and the DDC system."

3-2.10.3 Section 1107 Piping Material.

1107.1 – Piping location [Addition]

Insert after the last sentence of Section 1107.1:

"For refrigerant piping runs longer than 50 ft (15 m), size refrigerant piping in accordance with manufacturer requirements."

3-2.11 IMC CHAPTER 12 HYDRONIC PIPING.

3-2.11.1 Section 1201 General.

1201.2 – Sizing [Addition]

Insert after the last sentence of Section 1201.2:

"Provide back-up or standby pumps with lead/lag controls so that the total system capacity is available with any one pump out of service. On variable flow systems, maintain a minimum system flow of 20-30% of peak flow to avoid pump dead-head and overheating.

\1 For all centralized equipment such as chillers, boilers, and cooling towers, provide piping connections with valves and caps or blind flanges to allow for temporary equipment to be installed if the primary equipment fails." **/1/**

1201.4 - System types [Addition]

"Hydronic systems for comfort applications must be four pipe hydronic heat cool system (4-pipe independent load system). Piping material for **\1** building loop **/1/** hydronic distribution systems must be either copper or steel except for ground-source heat pump ground loop heat exchangers **\1** Ground-source heat pump systems ground loop heat exchanger piping must be Standard Dimension Ratio (SDR) High Density Polyethylene (HDPE)." **/1/**

1201.5 - Safety [Addition]

"For safety purposes, low-temperature hot water (250°F (120°C) and below) must be used where terminal equipment is installed in occupied areas. Medium-temperature (250 to 350°F (120 to 175°C)) hot water or high-temperature (350 to 400°F (175 to 200°C)) hot water 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 ft (4 m) above floor level."

1201.6 - Freeze protection [Addition]

"Freeze protection must be provided by automatic circulation of hydronic pumps when the outdoor temperature drops below 35°F (2°C), or by the addition of an appropriate antifreeze solution, or design of a pipe temperature maintenance systems (Example: heat trace) based on the lowest recorded temperature in the engineering weather data. Use the engineering weather data required in accordance with paragraph 2-6.2 Outdoor Design Conditions. For hydronic systems not needed for winter months, freeze protection may also be accomplished by draining the system prior to seasons that may experience freezing temperatures.

1201.7 - Hot Water System Modulation [Addition]

"Systems using hot water as a heat source must be controlled by a master outdoor temperature sensing unit that modulates the hot water temperature according to the outdoor temperature with a positive cut-off above 65°F (18.3°C) except when hot water is used for reheat."

3-2.11.2 Section 1204 Pipe Insulation.

1204.2 – Required thickness [Replacement]

Replace Section 1204.2 with the following:

"1204.2 Required thickness. Hydronic piping must be insulated to a minimum thickness as required by ASHRAE Standard 90.1. Follow the MICA *North American Commercial & Industrial Insulation Standards* for proper installation of field applied insulation."

3-2.11.3 Section 1205 Valves.

1205.1.5 – Equipment and appliances [Replacement]

Replace the last sentence of Section 1205.1.5 with the following:

“Provide shutoff valves to isolate all pumps, air separators, metering devices, and similar equipment.”

3-2.11.4 Section 1206 Piping Installation.

1206.1 – General [Addition]

Insert after the last sentence of Section 1206.1:

“Conceal piping in permanent-type structures. Exposed piping attached to or near equipment, or subject to high heat or frequent washing, must be copper, brass, or chromium plate. Prime other exposed piping with paint suitable for metal surfaces and finish-paint with color to match background. Arrange piping runs to minimize interference with personnel and equipment. Provide strainers upstream of all coils, pumps, and heat exchangers. Provide pressure and temperature test ports (P/T ports or "Pete's Plugs") on the inlets and outlets of all coils, pumps, chillers, heat exchangers, and other equipment. No additional “minor” losses (Examples: bends, elbows, fittings, or valves) are allowed between the inlet and outlet test ports. Provide expansion loops and devices as required for proper piping protection. Detail and dimension loops and schedule joints indicating minimum total traverse and installed expansion traverse. Indicate guide spacing. Avoid the use of expansion joints where possible due to the high resultant thrust. Instead use geometry and ball joints where possible. Where chemical feeders are provided, fill openings must be no higher than 4 feet (1.2 meters) above the finish floor for ease of filling. Hydronic piping must not be installed within or pass through electrical or communication rooms **\1** except as allowed, in writing, by the real property owner. **/1/** Where feasible, route hydronic piping through pipe chases and hallways. Where hydronic piping must route through occupied spaces, conceal in walls or ceilings. Route hydronic piping in accessible locations to maximum extent possible.”

1206.2 - System drain down [Addition]

Insert after the last sentence of Section 1206.2:

“Provide drain lines from air handling units, fan coil units, pressure relief valves, and backflow preventers. Provide a water seal on drains as required. Pipe drain valves to floor drains where possible. Where not possible, provide hose connection. Provide manual type air vents.”

3-2.11.5 Section 1207 Transfer Fluid.

1207.2 Makeup water [Addition]

Insert after the last sentence of Section 1207.2:

"Provide automatic makeup water system for each hydronic system. Protect potable water systems in accordance with UFC 3-420-01. Provide pressure gauges up and downstream of the pressure reducing valve. Provide bypass line with a globe valve for each pressure reducing valve.

For systems that use antifreeze solutions such as glycol, provide a feed system appropriate for the transfer fluid."

3-2.12 IMC CHAPTER 13 FUEL OIL PIPING AND STORAGE.

3-2.12.1 Section 1301 General.

1301.1 – Scope [Replacement]

Replace section 1301.1 with the following:

"1301.1 Scope. This chapter governs the design, installation, construction and repair of fuel-oil storage and piping systems. Use Chapter 13 and UFC 3-460-01. If any conflict occurs between Chapter 13 and UFC 3-460-01, the requirements of UFC 3-460-01 take precedence."

3-2.13 IMC CHAPTER 14 SOLAR THERMAL SYSTEMS.

3-2.13.1 Section 1401 General.

1401.1 – Scope [Replacement]

Replace section 1401.1 with the following:

"**1401.1 Scope.** This chapter governs the design, construction, installation, alteration and repair of systems, equipment and appliances intended to use solar energy for space heating or cooling, domestic hot water heating, swimming pool heating or process heating. Additionally, comply with UFC 3-440-01. UFC 3-440-01 takes precedence in any conflict with IMC Chapter 14."