
Introduction to HVAC Systems for Medical Facilities

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An Introduction to HVAC Systems for Medical Facilities



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1. GENERAL.

The primary requirement of the heating, ventilating and air conditioning (HVAC) systems in a medical facility is the support of medical function and the assurance of occupant health, comfort, and safety. The HVAC system functions not only to maintain minimum requirements of comfort and ventilation, but is an essential tool for the control of infection, removal of noxious odors, dilution and expelling of contaminants, and establishment of special environmental conditions conducive to medical procedures and patient healing. Subject to the above, appropriate consideration shall be given to the HVAC design to ensure system maintainability, economics and energy efficiency, and adaptability to future facility modification or expansion.

This presentation is intended to provide an introduction to heating, ventilating and air conditioning systems in medical facilities. It is not intended as a definitive treatise or design manual.

1.1 Applicability. This criteria applies to new and existing medical facilities including hospitals, medical and dental clinics, veterinary clinics, medical supply warehouses, medical training facilities, and medical research laboratories. Applicability to existing facilities is restricted to upgrade or replacement projects, and for those specific systems or services included in the scope of the project authorization. For existing facilities, when complete compliance with the technical criteria of this section is not economically practicable, consideration shall be given to substitution of other recognized industry standards or criteria. All facilities shall comply with the applicable standards of the National Fire Protection Association (NFPA).

2. DESIGN CONDITIONS.

2.1 Weather Data. Weather data shall be obtained from a recognized source. A recommended source is Unified Facilities Criteria 3-400-02 available without charge at www.wbdg.org.

2.2 Interior Design Conditions. Interior design conditions shall be in accordance with Unified Facilities Criteria 4-510-01 (available without charge at www.wbdg.org) or other recognized source such as ASHRAE publications.

2.3 Space Ventilation. Minimum total and outside air change rates shall be as indicated in UFC 4-510-01; Computed on a per-occupant basis, minimum outside air ventilation shall meet the worst-case requirements of either UFC 4-510-01, or ASHRAE Standard 62.1. Higher air change rates may be required to meet air conditioning or makeup air requirements as supported by engineering calculations.

2.4 Ambient Design Dry and Wet Bulb. The HVAC cooling design for facilities housing critical care and other inpatient services shall be based on the 0.4% Dry Bulb (DB), and corresponding Mean Coincident Wet Bulb (MCWB) temperatures, and winter heating design shall be based on the 99.6% DB. Cooling towers shall be designed on the basis of the 0.4% dew point temperature. Clinical facilities shall in general be designed to the 1.0% DB/MCWB temperature for cooling, and 99% level for heating. Cooling towers shall be designed on the basis of the 1.0% Wet Bulb temperature.

2.5 Critical Care Spaces. NFPA-99 and 70 discuss various minimum safe practices, and safety requirements for "General Care", "Critical Care" and "Wet Locations." The following patient care areas for hospitals have been identified by reputable authority as "Critical Care Areas" where patients may be subjected to invasive procedures and connected to line-operated electro-medical devices:

- a. Operating rooms.
- b. Delivery rooms and Labor and delivery rooms.
- c. Cystoscope rooms.
- d. Oral Surgery Maxillofacial surgery, Perodontics, and Endodontics.
- e. Recovery (surgery, and labor recovery beds).
- f. Coronary care units (patient bedrooms).

- g. Intensive care unit (patient bedrooms).
- h. Emergency care units (treatment/trauma/urgent care rooms and cubicles).
- i. Labor rooms (including stress test and preparation).
- j. Intensive care and isolation care nursery.
- k. Cardiac catheterization.
- l. Angiographic exposure room.
- m. Hemodialysis (patient station).
- n. Surgery suite preparation and hold.
- o. Hyperbaric chamber.
- p. Hypobaric chamber.
- q. Radiation Therapy (including simulator room).
- r. Nuclear medicine (camera room).

2.6 Sensitive Spaces. Sensitive areas include Automated Data Processing (Computer) rooms, Radiology and MRI computer rooms, selected laboratories (see below), and Telephone Switch Room. Other rooms housing sensitive electronic or other equipment or processes may be designated as Sensitive Areas on an individual project basis. Design ambient temperatures shall generally be the 0.4% DB/0.4% MCWB (summer), and 99.6% DB (winter). Each application should consider using 1.0% DB/1.0% MCWB (summer), and 99% DB (winter) design conditions for less critical equipment/process air conditioning requirements.

2.6.1 Laboratories. Space design temperatures for laboratories are indicated at UFC 4-510-01, generally 26°C (78.8°F). However, designers shall be responsible to coordinate with the equipment designer and user to establish whether temperature-sensitive equipment is expected to be utilized in a laboratory space. When such equipment requires, for proper operability or to meet warranty limitations, an ambient temperature lower than can be maintained by the HVAC/Control System when set at 26°C (78.8°F), the designer shall coordinate with the user to establish a reasonable lower design temperature for that space.

2.7 Temperature during Smoke Control Operation. When a supply air system is required to operate on 100% outside air during smoke mode operation, the system shall be designed with sufficient heating capacity to maintain a minimum of 45 degrees at the air handling unit discharge under the 99.6% winter design conditions.

2.8 Mechanical Equipment Rooms. In general, mechanical equipment rooms shall be designed with ventilating systems which will maintain temperatures within 5.5C of summer ambient design temperature. However when these equipment rooms house temperature-sensitive electronic components, such as microprocessor based controls, electronic circuit breakers, etc., designers shall confirm the ambient requirements of such equipment and design accordingly. In humid climates, mechanical rooms which are contiguous with the occupied building shall be conditioned to a humidity level equivalent to the occupied areas, to minimize transfer of moist, unconditioned air to the interior of the building.

2.9 Humid Climate Definition. A humid climate, as referenced here, is a region with 4,500 or more cooling degree days (50°F basis) that receives 20" or more of annual precipitation.

3. REFRIGERANTS.

Refrigeration equipment shall utilize refrigerant having an Ozone Depletion Potential (ODP) of not greater than 0.0 (refer to the EPA Significant New Alternatives Program (SNAP) for acceptable refrigerants). Refrigeration room design shall include the safety features, such as sensing devices, purge ventilation system, etc., as required for the particular refrigerant in accordance with ASHRAE Standards 15.

4. LIFE-CYCLE-COST/ENERGY ANALYSIS.

Life cycle cost and energy analysis required in conformance with this Section, or necessary for the evaluation of building sustainability features or performance, shall be in accordance with appropriate criteria.

5. APPROPRIATE SPACES FOR AIR CONDITIONING.

5.1 Total Air Conditioning. Air conditioning is required in all normally occupied facilities and spaces in which the interior conditions listed in UFC 4-510-01 cannot be met through natural ventilation alone. “Normally occupied spaces” will include such spaces incidental to medical facilities as corridors and circulation areas. Normally unoccupied, or intermittently occupied, spaces such as restrooms, locker rooms, soiled linen rooms, janitors closets, and similar spaces accessible to medical staff or the public and having exterior exposure shall be air conditioned (in addition to being provided with the required ventilation) to maintain reasonable conditions.

5.2 Food Service Area. Air conditioning of the kitchen areas shall be designed to avoid the waste of energy. Designs shall consider utilizing dining room transfer air or tempered make-up air for vented equipment exhaust, spot cooling, exhaust system heat recovery, and other energy saving strategies to minimize energy costs while providing a *reasonably* comfortable environment for kitchen staff.

5.3 Not Air Conditioned Spaces. In non-humid climates, the following areas are generally not provided with air conditioning. Heating and/or ventilation shall be provided as required to meet criteria.

- a. Motor Vehicle Storage Area
- b. Energy (Boiler/Chiller) Plants
- c. Mechanical Equipment Rooms, unless containing sensitive electronic equipment requiring temperature control.

d. Toilets/Showers and Locker Rooms not located with outside exposure. Note that locker rooms which do not include a shower room or toilet may be recirculated.

5.4 Medical Warehouses. HVAC design shall be based upon the environmental requirements of the stored materials. Spaces within medical warehouses which will be normally occupied, including Administrative or Break rooms, shall be air conditioned as required to provide the design conditions listed in Appendix A. Air conditioning will also be required for any warehouse spaces housing computer or other environmentally sensitive equipment.

6. MECHANICAL EQUIPMENT SPACE.

6.1 Mechanical rooms for major air handling equipment, heat exchangers, prime movers, medical gas supplies, vacuum/air compressors, and other major mechanical equipment shall generally be located within the facilities with access to the outside of the building. Exceptions to locate equipment in penthouse equipment rooms may be considered by the designer if justified from a cost or functionality standpoint and if properly coordinated with the base/post engineers. Rooftop mounted air handlers should be avoided due to the difficulty of maintenance access, and consideration of safety and working conditions for O&M personnel. Mechanical room location and layout shall consider:

- a. Sufficiency of space to enable access for operation, maintenance, and replacement of equipment.
- b. Minimization of distribution runs.
- c. Relative location to electrical equipment rooms: NEC vertical clearance/dedicated space requirements for electrical equipment will restrict or preclude the routing of piping and ductwork through these locations.

- d. Relative location to communication rooms: adjacency of fan and communications rooms will create congested above-ceiling conditions where cable trays and ductwork converge.
- e. Adjacency to corridors, as a path for the routing of ductwork.
- f. Adjacency to spaces having stringent noise control requirements, or spaces with high ceilings which may restrict duct distribution space.
- g. Potential future expansion of mechanical system capacity.

6.2 Chilled water and steam/hot water generators may be located in a separate energy plant. Utility lines connecting the energy plant to the facility shall be installed in a tunnel or other *accessible* enclosure providing maintenance access and protection from the elements.

7. HVAC SYSTEM DESIGN FOR FUNCTIONAL AREAS

For HVAC design, a medical facility can be considered to contain six general areas including Critical, Sensitive, Clinic, Administrative, Support areas, and Patient Bedroom areas. The primary considerations of the HVAC design are to provide the environmental conditions required to meet the functional requirements. Multizone, dual-duct, terminal reheat, variable air volume, and combinations of such air distribution systems may be considered for application in appropriate areas. If utilized, VAV systems will be of the minimum air quantity type. Furthermore, Direct Expansion (DX) coils shall not be used in Variable Air Volume systems. All-water, unitary, and fan-powered VAV systems will generally not be acceptable in medical facilities, due to their limitations in meeting ventilation requirements, increased contamination source potential, or increased maintenance requirements.

7.1 Critical Care Spaces. These spaces will normally be served by single duct terminal reheat or double duct systems. Simultaneous temperature, humidity, *and pressurization* control requirements for these spaces preclude the use of other types of systems.

7.1.1 Operating & Delivery Room (OR and DR) Air Systems. The room air supply system for Operating Rooms, Delivery Rooms, Cardiac Catheterization (hospital) Rooms, and Cystoscopy (hospital) Rooms shall be a ceiling supply type, located over the operating table or treatment area, using non-aspirating "low velocity" (0.2 - 0.41 m/s)(40-90 fpm) diffusers that isolate the air over the operating or treatment area. Room exhaust/return provisions shall consist of a minimum of two exhaust or return registers, located at diagonally opposing corners of the room, mounted with bottoms of registers between 150 mm (6 in) and 230 mm (9 in) above finished floor. The HVAC system for anesthetizing locations, including operating and delivery rooms, shall be designed in accordance with NFPA 99 to (a) prevent recirculation of smoke originating within the surgical suite and (b) prevent the circulation of smoke entering the system intake, without in either case interfering with the exhaust function of the system.

7.1.2 Continuity of Service. The design for the HVAC systems serving Critical Care spaces shall include the following:

a. The Air Handling Unit(s) (AHUs) serving Operating or Delivery Room suites shall be separate, independent units serving only the respective Surgical or Obstetrical Department or portions thereof, to enhance the reliability of these systems and minimize demand on the emergency power system. The air handling unit(s) serving each suite may also provide service to other Patient Care or support areas outside the respective Surgical or Obstetrical Department. A maximum of four ORs or four DRs should be served by any single AHU. Where a facility has four or fewer ORs, these should be served by at least two separate air handling systems, to enhance reliability; a similar consideration should apply for DRs.

b. HVAC equipment, including controls, which serve Critical Spaces (including ventilation and pressure controls for isolation bedrooms) shall be connected to the emergency electrical power system. This shall include a

sufficient number of chillers and boilers, with necessary supporting equipment, to meet critical design loads. Boilers shall have dual-fuel burners that are not solely dependent on one source of fuel for ignition.

c. Designs shall include features to minimize HVAC service interruptions to Critical Care spaces, without the provision of redundant air handling units or distribution systems. Provisions shall be such that service interruption to any Critical Care space, as a result of failure of an air handling unit component or its supporting electrical or controls systems, shall be minimized. Such features may include the provision of multiple, isolatable, heating and cooling coils, spare stock of replacement motors, drive belts, and bearings in the immediate vicinity of the equipment room, dual fan units, "manifolded" ductwork connections between AHUs, or other measures providing for continuity or expeditious restoration of service.

d. Air Handling Units, with associated controls, which serve critical care spaces and patient bedrooms shall be connected to the electrical emergency power system.

7.2 Sensitive Areas. These are spaces or areas in which equipment or processes may require special environmental control, including continuous (24 hours per day, year-round) air conditioning and individual room temperature and/or humidity control. Economic or operational considerations normally dictate provision of independent air conditioning systems for Sensitive Areas, to enable continuation of air conditioning when main building systems are shut down for repairs, or are operating in night setback or economizer mode. Minimum outside air ventilation shall be provided in normally occupied areas. For those sensitive spaces critical to continued hospital function and which require continuous cooling to remain in operation, appropriate backup or redundant features shall be provided to assure continuity of air conditioning in the event of primary air conditioning equipment failure. This may include the requirement for connection of air conditioning equipment to the emergency power system.

7.3 Administrative Areas. Administrative areas may be served by single duct reheat, multi-zone, VAV, or dual-duct systems, with perimeter radiation when required or advantageous.

7.4 Outpatient Clinics. Outpatient clinics may be served by single duct reheat, dual-duct, VAV, or multi-zone systems. Multi-zone systems may only be employed if the following conditions are considered: 1) ease of mechanical room duct egress, 2) no large disparity in zone size or load profile, 3) little likelihood of space repartitioning or rearrangement, and 4) proximity of space served to the mechanical room.

7.5 Support Service Areas. Support service areas may be served by single duct reheat, dual-duct, VAV, or multi-zone systems.

7.6 Patient Bedrooms. Normal-care Patient bedrooms may be served by dual duct, multi-zone, VAV, or single duct reheat systems. All systems utilized shall maintain minimum ventilation quantities under all conditions of operation. Perimeter radiation systems (radiant panels) may be considered in conjunction with these air systems. Fin-tube heating systems shall not be used in patient bedrooms.

7.7 Patient Isolation Bedrooms. Isolation bedrooms shall be served by airflow systems which maintain a constant differential between supply and exhaust air flow rates to maintain the required relative pressurization of the space to the adjacent spaces and corridor. Refer to more detailed design guidance and requirements for isolation bedrooms below. Pressurization control equipment serving Protective Isolation and Disease Isolation Bedrooms shall be connected to the emergency electrical power system.

8. GENERAL DESIGN CONSIDERATIONS

8.1 Plant Sizing and Optimization. For all facilities justifying a degree of redundancy in the capacity of primary energy plants, the precise number, capacity, and configuration of primary heat exchangers and pumps shall be determined in accordance with the following requirements.

8.1.1 Facilities with Critical Environments. These facilities include all medical facilities with inpatient functions, and for selected Research and Vivarium facilities in which loss in ability to condition the facility would result in loss of critical research or animals at prohibitive cost. The plant shall be sized and configured such that:

- For inpatient medical facilities, with one major heat exchanger or pump out of service, the remaining plant equipment is sufficient to serve all critical loads, including patient bedrooms and labor rooms, plus one half of all remaining loads within the facility.
- For Research and Vivarium facilities, with one major heat exchanger or pump out of service, remaining capacity shall be sufficient to serve the critical environmental loads, plus all support spaces, such as computer records, critical to the continued operation of the facility. This will not include routine office, conference, classroom, or administrative areas.
- For all facilities with critical environmental requirements, with one major heat exchanger or pump out of service for an extended period (one day or more) of maintenance, during the “off” season for such service, the remaining plant equipment shall be sufficient to meet the entire facility’s maximum load.
- For all such facilities, plant optimization shall in addition be based on life cycle cost analysis of the most life-cycle economical number, capacity, and configuration of prime heat exchangers and pumps.

8.1.2 Energy Plants for Outpatient Clinics. When energy plants consisting of multiple primary heat exchangers are justified, on a project by project basis, for large Outpatient

Clinics, the plant shall be designed on the basis of life cycle cost analysis of the most life-cycle economical number, capacity, and configuration of prime heat exchangers and pumps.

8.2 Contaminant Removal. HVAC systems shall be designed to remove or reduce to acceptable levels volatile chemical and airborne microbiological contaminants within the facility. Systems shall be designed to remove excessive moisture in facility spaces and to control moisture and dust accumulation in air handling units, distribution elements, and chases, to avoid conditions permitting the growth of pathogenic, allergenic, or otherwise objectionable microorganisms.

8.3 Interdepartmental Air System Restriction. In general, individual facility departments should be served by dedicated air handling systems in order to increase system flexibility, energy conservation, facilitate comfort control, and reduce demands upon the emergency power system.

8.4 Air Filtration. Individual space air filtration shall be provided as indicated at UFC 4-510-01. MERV 8 "roughing" filters shall be provided upstream of all coils, velocity sensing devices, or other devices requiring protection from dust accumulation. "Roll filters", cleanable media, or other filtration systems requiring more intensive maintenance should be avoided. Designers shall carefully consider the location of filters relative to humidifiers to minimize the possibility of wetting the filter media. Use of bag type filters should be avoided for critical care spaces due to the propensity for bag filters to release particles during air handler startup/shutdown.

8.5 Balancing Ports and Features. Necessary controls, instrumentation, and balancing ports and devices shall be provided to establish and maintain the required space temperature, relative humidity, and air changes rate, and to facilitate balancing procedures for all systems.

8.6 Additions and Alterations to Existing Facilities.

8.6.1 Site Investigation. Designers shall conduct thorough investigations of existing facilities to be upgraded or modified, to become knowledgeable with facility conditions, as established by the terms of their design contracts. This includes the need to inspect concealed spaces (above-ceiling plenums, equipment rooms, chases, etc.) to permit evaluation and accurate depiction of as-built conditions which can affect new work. Design agents shall assure that this requirement is met; it is advantageous that the expected scope of the site investigation be discussed in detail with the designer during project pre-negotiation and “kickoff” meetings. Generally, designers should be required to directly inspect all equipment rooms and all above-ceiling areas in such a number of locations as to reasonably establish the existing conditions. In facilities with “hard” ceilings, this may require the creation of a suitable number of inspection openings: design agents shall define in Project Design Instructions the responsibility for making and repairing such openings. Structural and architectural building elements, as well as existing equipment, that restrict equipment distribution space should be directly verified to the extent reasonably practicable. The design team must recognize the economic advantages of a detailed designer site investigation: if the designers do not verify conditions, the construction contractor must do so, normally at a cost premium reflected in higher bidding costs (unknown conditions) and change orders (changed conditions).

8.6.2 Modifications to Existing Systems. Too often in the past, addition/alteration project design documents have failed to provide the detailed engineering guidance required to sustain operation of systems serving occupied areas, leaving this engineering responsibility in the hands of QA personnel or construction contractors. The results have included loss of critical services, inadequate system performance, project completion delays, and costly change orders. Therefore it is hereby emphasized that it is the responsibility of the project designer to carry out all aspects of the design which can reasonably be accomplished during the design phase. Modifications to existing equipment and systems, including temporary connections, changes to system performance, or measures necessary to sustain service, shall be shown and described

in detail in project design documents. Designers shall evaluate the impact on existing systems of extensions of service which increase system demand. The locations of new connections shall clearly be shown and/or described. The designer shall determine, and document for the design agent's information, any project work which will necessitate a reduction or interruption of any service to an existing, occupied area.

8.6.3 Protection of Patients From Construction Contaminants. For additions or alterations to existing hospitals, measures shall be provided to minimize contamination of existing hospital areas, during the construction period, and the associated HVAC systems serving them. Measures to reduce the potential of contamination and nosocomial infections include but are not limited to negative isolation of construction areas, construction of effective dust barriers (including double barrier air locks at entrances and exits) separating construction from occupied areas, protection of air distribution systems serving occupied areas, and disinfection of any reused ductwork. Designers shall consult with the facility's infection control representative during the design process to assure thorough coordination of design features that may affect patient welfare. See also the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guideline for Occupied Buildings Under Construction.

8.6.4 Construction Phasing Plan. Designers shall develop a phasing plan, consisting of detailed written instructions as well as any graphic/drawing aids necessary to clearly communicate the content, location, and sequence of work activities. The plan shall identify the scope, duration, and timing sequence of each individually identifiable work item, with all required lead-in, preparatory, and commissioning activities.

8.6.5 Commissioning Considerations. More so than in new, stand-alone facilities, off the shelf guide specifications fall short of providing for all of the required commissioning procedures. In particular, designers shall show and specify the procedures required for interim, as well as final, commissioning for systems constructed (or altered) and placed in operation segmentally.

8.7 Cooling and Heating Load Calculations

8.7.1 Heating Load Calculation. Calculations used for determination of primary and airside (including reheat) heating equipment should not include credit for internal load sources, including lighting, people, and equipment. These loads are typically not present, or are much reduced, at night and on weekends. Heat calculations should also take into consideration morning warmup loads when night setback temperatures are utilized in non-ward areas.

8.7.2 Equipment Heat Generation. In many spaces within facilities, the primary component of cooling loads will be equipment heat generation. It is therefore necessary for accurate load determination that the HVAC designer coordinate on a project-by-project basis with the equipment designer, and with the individual Using Agency, to identify all individual equipment items and the corresponding load contributions. To estimate equipment usage duration and frequency, designers shall gather information from the Using Military Department, or if unavailable from that source the manufacturer, personal experience, or other sources. Determine average heat output from manufacturer's information. In performing load calculations, designers shall consider the as-designed equipment provisions of each unique space. "Rules of thumb" loading assumptions are not acceptable for final design calculations.

8.7.3 Lighting Loads. Lighting loads present a significant component of medical facility cooling loads and as such require consideration of the as-designed lighting fixture numbers and characteristics of each space. "Rules of thumb" lighting load assumptions are not acceptable as the basis for final design load calculations.

8.7.4 Envelope Components. Minimum insulation values for building envelope components shall be in compliance with Unified Facilities Criteria 3-400-01 (available without charge at www.wbdg.com). U-value calculations shall take into consideration the "fin effect" of metallic elements of wall and roof construction, as for example the

effect of steel studs in walls which may as much as halve insulating effectiveness of batt insulation.

8.8 Piping Systems.

8.8.1 Pipe Routing. Piping distribution systems should be routed above corridors whenever practicable, to minimize leaks, maintenance intrusion, and noise in occupied areas of the medical facility. Pipes shall not be routed through telecommunications rooms per ANSI/EIA/TIA-569-A.

8.8.2 Thermal Expansion. Designers are responsible for designing all aspects of piping systems necessary for the control of thermal expansion, and for showing the necessary control features on design drawings. This includes showing and dimensioning as applicable, the approximate locations of guides, anchors, expansion ells and offsets, and flexible couplings, as well as any other piping features which may affect expansion forces in the piping. The intent of this requirement is to assure that this critical aspect of piping design is accomplished by the qualified mechanical engineer selected for the project design, and not by a construction contractor of unknown engineering ability or qualification. In the case of direct-burial (i.e., pipe within a pipe) underground heat distribution systems, engineering of the expansion compensation features by the system manufacturer may be preferred or necessary. Designers shall design piping systems such that piping expansion forces are isolated from equipment. Design Agents shall provide that contractor's shop drawing layout drawings of hot piping systems are reviewed by the designer or by an equally competent engineer representative of the government.

8.8.3 Steam and Condensate Piping. Steam in excess of 20 psig shall not be distributed in above-ceiling areas of a medical facility, or in utility corridors or chases adjacent to normally occupied spaces unless substantial concrete, masonry, or metal protective barriers are provided. Designers shall show the required direction and degree

of line slope on drawings, and shall provide and show the locations and details of drip traps and other drainage features.

9. HVAC SYSTEM CONTROLS

9.1 Energy Conservation. All designs shall comply with UFC 3-400-01.

9.2 Temperature Control. Individual room temperature controls shall be provided for all Critical spaces, Sensitive spaces, Patient Bedrooms, Labor Rooms and Laboratories, to closely maintain the room conditions provided at UFC 4-510-01. Zoned temperature control shall generally be utilized for other spaces within the facility. Only rooms with similar exposures and load profiles shall be served by a single zone. All conference rooms, classrooms, and other rooms with unique exposures or load profiles shall be served by a single zone. All variable volume terminal controllers serving normally occupied spaces shall be provided with a means of reheat, if a separate means of room heating (such as perimeter heating) is unavailable.

9.3 Control Precision. Temperature controllers shall maintain space temperature within $\pm 1.1^{\circ}\text{C}$ (2°F) of design setpoint, as provided for the individual spaces at UFC 4-510-01. The summer and winter design setpoints normally differ. For some spaces, a temperature range is given as the summer, or winter, interior design condition in lieu of a specific temperature setpoint. The HVAC system for such spaces shall be designed with the capability, under design conditions, to maintain any selected temperature within that range.

9.4 Humidity Control.

9.4.1 Humidity controls shall be provided as necessary to meet the requirements given for individual spaces at UFC 4-510-01. Humidity controls shall be provided on a room basis for the following critical spaces:

- Operating Rooms
- Surgical Delivery Rooms
- Cystoscopy Rooms

Humidity controls for all other spaces may be provided on a zone or system basis as determined to be sufficient to maintain the required conditions. Note that for spaces for which precise relative humidity requirements are not stated, humidity controls may be required to maintain an envelope of 30% to 60% RH during normally occupied hours; for such spaces, designers shall determine the likely interior RH, based upon outside air conditions and interior latent loads. Humidifiers are problematic from a maintenance standpoint, and should not be utilized except when analysis indicates that RH will drop below 30% for significant amounts of time.

9.4.2 Humidifying Equipment. Air handling system humidification shall be achieved utilizing direct steam injection. Designers are responsible to designate the location of steam injectors relative to ductwork and air handling unit components, and so design them as to minimize concerns with moisture collection in/on the downstream elements. Provide a minimum of 3 M (10 ft) of straight ductwork, with no takeoffs, reducers, duct lining, or other components, immediately downstream of the injection location; If this separation space is not available, the design engineer shall provide a detailed design, considering duct dimensions, airflow velocity and psychrometric condition, and number and location of injection orifices, with necessary instructions to the construction contractor, to maximize the probability of moisture reevaporation before impact with downstream elements.

9.4.3 Trim Humidification for Critical Spaces. Humidifier shall be separated a minimum 4.5 M upstream from high efficiency final filtration; when this separation cannot practicably be achieved, a detailed design for the humidifier shall be provided.

9.5 Direct Digital Controls (DDC). The Direct Digital Control System shall be a complete system suitable for the control of the heating, ventilation and air conditioning

system and other building level systems as specified. When a Using Agency determines that communication between a facility's DDC system and a remote Utility Monitoring and Control System (UMCS) is required, the design shall assure that the DDC system is seamlessly compatible with the UMCS system.

9.5.1 Utility Monitoring and Controls Systems (UMCS). No remote UMCS system (i.e., not located in the medical facility or its associated energy plant) shall be permitted to exercise control over any hospital HVAC system equipment providing service to Critical Care Spaces. Remote UMCS systems may be provided with monitoring, alarm, and reporting capabilities as necessary to facilitate maintenance activities.

9.6 Air Handling Equipment Control

9.6.1 Building Pressure Control. All systems shall maintain the building at relative positive pressure to the outside environment, with the exception of those spaces on perimeter walls required to maintain a negative pressure relative to contiguous spaces. For facilities in humid climates, and for all facilities of three stories or more in height, automatic controls shall be provided to actively monitor and control building pressurization via pressure monitoring at strategic locations on each level, and manipulation of outside air and/or exhaust volume flow rates. All systems which modulate outside air, including all VAV air handling systems, shall include accurate airflow measurement arrays located in accordance with manufacturer's recommendations as part of their control system.

9.6.2 VAV Air Handling Unit Controls. All VAV systems shall be provided with supply and return fans, with economizer operation where required and where economically life cycle cost effective. Fan speeds shall be modulated by means of variable speed drivers (VFDs). Supply fans shall modulate based upon maintaining a fixed static pressure at a location remotely located in the ductwork sufficient to assure operation of all VAV terminal devices. Supply, return, and outside airflow rates shall be measured by the DDC control system, and the return fan shall modulate to maintain a fixed differential

airflow below that of the supply fan. A high supply duct static sensor and shutdown capability shall be provided.

9.6.3 Variable Exhaust Controls. HVAC controls for laboratories, treatment rooms with coughing booths, autopsy procedure rooms, and other rooms having equipment requiring variable or intermittent exhaust requirements, shall be provided which maintain the required room relative pressurization and room conditions for all modes of operation of the equipment (i.e., on or off, minimal to maximum sash height, etc.), according to the User's intended operation. Variable flow controls shall be provided for the general exhaust of such rooms, as well as for the equipment, to allow measurement and tracking of supply to exhaust flow differential by the DDC system.

10. STEAM SYSTEMS

10.1 Humidification Steam Source. Steam generated by heating system boilers, (or any other steam) containing harmful concentrations of amines or other treatment chemicals, shall not be used for space humidification. Separate steam generators for humidification shall be provided. If authorized by user, central steam systems utilizing chemicals safe for human respiration (controlled within allowable limits) may be considered. The design shall include provisions to minimize the effects of system corrosion resulting from the heating of under-oxygenated water.

10.2 Sterilizer Steam Source. Steam generated by boilers located in an on-site (hospital-dedicated) boiler plant may be utilized for sterilization steam subject to approval by the individual military department. As hospital authorities cannot normally exercise a reasonable degree of supervision or control over treatment chemicals utilized in base-wide or district systems, steam from these sources may not be utilized for direct sterilization. Unlike humidification steam, which is injected directly into the air supply, little sterilizer steam will escape into a facility's general environment. Under a reasonably responsible boiler treatment program, any steam which does escape will not

result in dangerously high levels (OSHA RELs, etc.)of treatment chemicals in the environment.

10.3 Designer Qualifications. Projects involving the design of extensive medium or high pressure steam systems require the services of engineers highly experienced in this specialty. Too often, experience has shown that mechanical designers unfamiliar with steam system design err in the design of expansion compensation, condensate collection and handling, and equipment selection. Design Agents must insist on proper qualifications for designers of these systems.

11. AIR HANDLING AND DISTRIBUTION

11.1 Air Handling Unit Considerations. Air handling units are to be double wall, internally-insulated, readily maintainable units suitable for utilization in medical facilities. Draw-through units are normally preferred, to utilize fan heat to increase the dry bulb air temperature above the saturation point and minimize the possibility of wetting downstream filters, attenuators, or other components. Provide for access doors immediately upstream and downstream of all coils, to facilitate cleaning and proper installation of the unit freezestat.

11.2 System Shutdown Capability. To the extent practical and cost effective, non-critical, *non-bedroom* area HVAC systems shall be designed to permit shutdown (night setback/setup, outside air shutdown) of individual areas or departments not in operation on a 24-hour basis. *Ventilation of toilets, battery vaults, and other normally-exhausted spaces shall be continued without interruption as warranted.*

11.2.1 Air distribution systems shall comply with the requirements in UFC 4-010-01.

11.3 Outdoor Air Intakes. Outdoor air intakes shall be located as far as practical, but not less than 9000 mm (30 ft), from exhaust outlets of ventilation systems, cooling towers, combustion equipment stacks, medical/surgical vacuum systems exhaust,

plumbing vent stacks, emergency generator exhaust, or from areas which may collect vehicular exhaust and other noxious fumes. Locate the bottom of air intakes serving central systems as high as practical but not less than the distance above ground level required by UFC 4-010-01 (reference 7v), or if installed above the roof, at least 900 mm (3 ft) above roof level. Outdoor air shall not be drawn from equipment rooms. Designers must utilize judgment in the location of contaminant exhausts, and not simply apply the “9M rule” without further consideration of wind direction and velocity, building geometry, and characteristics of the contaminant stream. Appropriate consideration shall be given to prevailing wind direction, summer and/or winter as applicable; however designers are cautioned not to rely on prevailing wind direction(s) as a primary factor in the avoidance of intake contamination. In particular, use extreme caution in locating outside air intakes in proximity to parking areas, ambulance garages, loading docks, exhaust air outlets, and equipment stacks. Where appropriate, designers will provide in individual project design instructions for special computational fluid dynamics (CFD) or wind tunnel modeling to provide greater assurance of the correct location of outside air intakes.

11.4 Noise Control. Noise Criteria (NC) for individual rooms and spaces in the facility are provided at UFC 4-510-01.

11.4.1 Room Breakout. The HVAC designer shall coordinate with the architectural designer to control equipment noise passing from mechanical rooms into adjacent spaces through the surrounding walls or partitions.

11.4.2 Crosstalk. The compromising of patient privacy by transmission of audible speech from one room to another via ductwork is of great concern in medical facilities, and shall be addressed by HVAC designers. Examination rooms, physician's offices, and toilets require the designer's particular attention. Ductwork connecting adjacent rooms must have the necessary attenuating characteristics to eliminate audible speech transmission. Typically this is addressed by the provision of well-separated “takeoffs” and/or several duct elbows in the intervening ductwork.

11.4.3 Air Fixtures. Air distribution supply, return, and exhaust fixtures (diffusers, grills, etc.) shall be sized to provide air inlet/outlet velocities consistent with room NC level requirements as provided at UFC 4-510-01. Designers must be aware that diffuser manufacturer's published noise characteristics are based upon idealized inlet conditions: crinkled flex duct, abrupt branch duct connections, elbows located immediately at the diffuser collar, and similar poor connections may result in unacceptable noise levels. Spin-in or other 90 degree duct drop connections to diffusers shall be equipped with equalizing grids as necessary to assure uniform air distribution at the diffuser inlets.

11.4.4 Air Velocity. Designers shall limit air velocities in ductwork (see additional guidance below), air transfer grills, or door undercuts to values consistent with ASHRAE recommendations to control noise generation.

11.4.5 VAV/CAV Terminal Units. Variable Air Volume Terminal units and constant velocity controllers are a frequent source of noise generation in air distribution systems. Designers shall specify or schedule units with minimum inlet sizes for incremental ranges of flow, and shall indicate maximum sound power output for each unit, at the maximum inlet static pressure which the designer anticipates that the unit will be exposed to. If integral sound attenuating devices are required, these shall be indicated for the respective terminal unit(s) in specs or drawing schedules.

11.4.6 Exterior Noise Sources. Designers shall evaluate the sound characteristics of exterior equipment provided as part of the project design (such as cooling towers, emergency generators, etc.) to assure that such sources do not result in interior noise levels exceeding limitations provided in UFC 4-510-01.

11.5 Duct Design. Duct systems shall be designed in accordance with ASHRAE standards. Maximum velocity in ductwork mains shall not exceed 760 M/m (2500 fps), and velocities in branch ducts and takeoffs shall not exceed recommended levels in these standards. Ductwork plans shall indicate the static pressure class required for

sealing and reinforcement for all types of duct. Access panels shall be provided as necessary for access to fire dampers, smoke dampers, and control equipment, and to facilitate periodic cleaning or disinfecting of ductwork. All supply air, with the exception of air transferred between spaces for the purpose of pressurization, shall be provided in sheet metal ductwork.

11.5.1 Non Corrosive Ductwork Material. Ductwork installed downstream of high efficiency final filters (90% or greater, see UFC 4-510-01) or trim humidifiers, serving critical spaces, shall be of stainless steel, or aluminum, including all accessories such as dampers, fasteners, and turning vanes. This provision does not apply for ductwork downstream of high efficiency filters when these are located at the air handling units (filters noted in the “intermediate” column in UFC 4-510-01). Exhaust ducts for glass washers, dishwashers, and cart washers shall be non-corrosive and shall have soldered or welded joints and shall be pitched to drain.

11.5.2 Return Air Plenums. Corridors shall not be used as return air plenums in any portions of facilities. Exceptions allowing transfer air for toilets and janitor's closets, as provided in NFPA 90A and 101, shall be permitted. Utilization of above-ceiling areas as return air plenums shall not be permitted in inpatient or critical-care areas of facilities. Utilization of above-ceiling areas for return or exhaust air in portions of facilities not classified as healthcare occupancy is discouraged but may be considered on an individual project basis when justified and approved.

11.5.3 Duct lining. The utilization of duct lining materials is prohibited in all medical facilities. These materials may harbor dust and moisture, providing an ideal environment for the propagation of pathogenic or noxious microorganisms. Factory fabricated sound attenuators, packed type, which comply with ASTM C1071 and UL 181, shall be used to attenuate fan noise. No duct lining materials which are porous to the airstream may be utilized.

11.5.4 Balancing Provisions. Duct branches serving each individual space shall be provided with a manual balancing damper, accessible above the ceiling, located as remote from the space supply or return fixture (diffuser, register, etc.) as practicable. The balancing damper provided as part of air diffusers is not to be used for system balancing.

11.5.5 Telecommunication Rooms. Ducts shall not be routed through telecommunications rooms per ANSI/EIA/TIA-569-A.

12. MAINTENANCE PROVISIONS

12.1 General Personnel Access. Safe and practical means of personnel access must be provided to, and within, all areas of the facility where equipment is located, to adequately provide for operation, maintenance, and replacement (O&M) of the equipment. Access to equipment rooms from outside the facility should be provided where feasible. Within equipment rooms, provide clearance to all service points to mechanical equipment to allow adequate personnel access and working space in accordance with equipment manufacturer's recommendations; but as a minimum, maintain 0.75M (2.5 ft) at all service points and 1.7M (5.5 ft) of overhead clearance for O&M accessways. Proper clearance shall be provided such that personnel do not have to climb over equipment or crawl on hands and knees. When rooftop air handling units are provided, coordinate with the architectural designer to provide pavers or other personnel access pathways which will not damage the roof.

12.2 Equipment Clearances. Minimum clearances between electrical and mechanical equipment shall be as required by NFPA 70. Assure that practical means are provided for the removal/replacement of the largest and/or heaviest equipment item(s) located in the facility. Provide adequate pull space for all coils, heat exchangers, chillers, boiler tubes, and filters. Sufficient space shall be provided in above-ceiling areas to facilitate equipment installation and O&M. For building designs utilizing interstitial floor distribution zones, further guidance is required.

12.3 Suspended/Mounted Mechanical Equipment. Where suspended and mounted equipment is installed, provide a minimum of 1700 mm (67 in) of clearance for headroom as required. In refrigeration equipment rooms, provide overhead clearances required by ASHRAE 15. For any work station or location requiring maintenance access, which is not readily accessible from a 1800 mm (6 ft) high portable ladder, provide a fixed ladder and/or catwalk.

12.4 Air Distribution System Components. Outdoor air intake plenums, air handling unit casings, and distribution ductwork shall be designed to permit access for periodic cleaning or disinfection.

12.5 HVAC System Balancing Provisions. Adequate access shall be provided to facilitate operation, adjustment, and testing at all HVAC balancing and measuring points and equipment, including automatic and manual damper operators, air terminal units, pilot tube ports, valves, and sensing devices.

13. VIBRATION CONTROL. All prime moving equipment shall be isolated to prevent transmission of vibrations to the structure.

14. INTERDISCIPLINARY COORDINATION

14.1 Fire Protection Features.

14.1.1 Smoke and Fire Dampers. HVAC service zones should be designed to coincide with smoke compartments whenever practicable. Ductwork penetrations of fire/smoke rated walls should be minimized, to minimize the required number of smoke/fire dampers and complexity of controls. Coordinate with the architectural design to assure that necessary access for inspection or service of these dampers is provided.

14.1.2 Ductwork. Air supply and exhaust systems shall be of the mechanical ventilation type and shall meet the requirements of NFPA 90A and 96. Grease-laden vapor exhaust ductwork shall be in accordance with NFPA 96.

14.1.3 Smoke Mode Operation. Comply with applicable standards and practices.

14.1.4 Commissioning of Fire/HVAC Systems. Guide specifications typically do not contain provisions for the simultaneous testing of HVAC and fire protection systems, which can have complex, interwoven operational requirements in some facilities. For each project where applicable, designers shall develop or modify specifications as needed to provide for testing of HVAC systems under fire alarm conditions, to permit verification not only of correct function, but of acceptable speed of response. In more complex systems involving smoke evacuation or compartmentalization/pressurization, detailed testing protocols and/or system diagrams must be developed to clearly convey the required scope of the commissioning effort.

14.2 Emergency Electrical Service.

14.2.1 Capacity. The HVAC system equipment serving Critical areas shall be connected to the essential electrical power system, to assure service continuation in the event of normal power disruption, in accordance with the requirements of NFPA 99. Cooling, as well as heating, shall be maintained to Critical areas in the event of normal power outage.

14.2.2 Commissioning. Service guide specifications do not adequately address testing requirements for HVAC/Emergency Power System (EPS) interoperability. HVAC systems connected to the EPS must be shown to function as intended under conditions of normal power interruption. Testing of the EPS must be conducted in conjunction with any components of the HVAC system required for support; For example, thermostatically operated louvers may be required in emergency generator rooms for makeup air, generator radiator cooling may be a function of such HVAC components as pumps or cooling tower, etc. Testing must verify the actual connection of HVAC

equipment to the EPS in accordance with the design following normal power outage, in the priority sequence established by the design. Designers shall supplement or modify guide specifications to assure that such verification testing is adequately detailed and described.

14.3 Seismic Design Requirements. Refer to appropriate standards and practices for seismic provisions for the HVAC system equipment and components. Designers shall be responsible to assure that seismic bracing of HVAC piping is coordinated by design with thermal expansion compensation features, to allow for the necessary pipe movement with temperature changes.

14.4 Design Coordination. Designers are responsible to coordinate the HVAC with the electrical, communications, architectural, and structural aspects of the design to assure that equipment can reasonably be installed by a contractor providing equipment, and following installation procedures, within the terms of his contract. For this reason, designers are instructed to base equipment room and distribution space designs upon spatial envelopes (including maintenance clearances) which will accommodate any of at least three manufacturers of major equipment. Routes of ductwork and piping must be carefully coordinated with other elements, considering required slope, insulation, bracing, reinforcement, slope, and maintenance access. This practice in no way infringes on or substitutes for the construction contractor's responsibility, to be defined in project specifications, to coordinate the installation work of all trades and to provide detailed shopdrawings showing the proposed construction; Rather, it assures that the contractor will be able to achieve his goal without the necessity of additional design work.

14.4.1 Equipment Rooms. To assure adequate coordination, designers must consider not only the HVAC equipment, but the work requirements of other trades. Assure adequate clearance around air handling units to permit bolting the units together and securing them to their housekeeping pads, meanwhile providing space for the general contractor to install wall partitions. Consider the locations of plumbing and medical gas

equipment. Assure it will be possible for maintenance workers to access all controls, electrical panels, valves, and instrumentation. Be aware of NEC clearance and vertical dedicated space requirements for electrical equipment. Coordinate ductwork, outside air plenums, etc. with the locations of lighting.

14.4.2 Above-ceiling Plenums and Chases. Designers must anticipate the worst case insulation, duct reinforcement, equipment support, slope, and fitting characteristics associated with ductwork and piping distribution systems, and be careful to coordinate the location of these systems with other equipment, including in particular cable trays and lighting fixtures with their vertical access/clearance space requirements. Assure that access space is considered for damper operators, low point steam drip assemblies, VAV terminal units, reheat coil controls and instrumentation, service valves, and access doors for ductwork for cleaning or damper inspection.

15. FUEL STORAGE REQUIREMENTS

Refer to appropriate standards and practices for fuel storage requirements for facilities in seismic threat regions. Additional fuel storage guidance for boiler plants shall be obtained from the individual service criteria

16. VENTILATION DESIGN

16.1 Ventilation Air Changes. Minimum air change rates for each space, for both outside air and total air, are provided at UFC 4-510-01. Ventilation rates contained in ASHRAE Standard 62.1 shall be applied for spaces or applications not addressed by UFC 4-510-01. Based on the number of occupants identified for each space, calculate the outside air requirements of ASHRAE 62.1 and compare to the rates given in UFC 4-510-001, utilizing the more stringent figure in the design. The minimum outside air change rates in Critical Care Spaces shall be maintained at all times, except as addressed elsewhere in this Section for Operating and Delivery Rooms during periods of non-use. Reduced outside air ventilation in noncritical areas may be considered

during non-occupied times. In addition, a Corrected Outside Air Ratio, calculated in accordance with ASHRAE 62.1 section 6.2.5, may be applied for non-critical spaces. The outside air ratio for non-critical high-occupancy spaces, including classrooms, waiting rooms, auditoriums, and conference rooms, may be adjusted in accordance with the provisions of ASHRAE 62.1 section 6.2.6 when the maximum occupancy peaks for a duration of less than three hours.

16.2 General Exhaust Provisions. Exhaust systems shall be provided for Central Sterile Decontamination(Ethylene Oxide), animal holding areas, autopsy/morgue spaces, laboratory fume hoods, radioisotope hoods, bacteriological cabinet, kitchens, laundry, toilets, isolation rooms, equipment rooms, and other areas as noted in UFC 4-510-01 or as designated on an individual project basis. No duct system conveying potentially hazardous exhaust (ETO, lab hoods, etc.) shall be connected with a general or toilet exhaust system. All exhaust discharge outlets shall be located above the building roof line and located to prevent short-circuiting to air intakes or other building openings. Exhaust fans shall be located at the end of the exhaust duct run (exhaust ducts to be under negative pressure).

16.3 Space Pressurization. The required pressurization of individual spaces, relative to adjacent spaces or corridors, is indicated at UFC 4-510-01. Where a negative or positive pressurization are required for a given space, that pressurization shall be maintained by the HVAC system under all conditions of operation, including periods of reduced ventilation or night setback.

16.4 Laboratory Ventilation. Exit corridors shall not be utilized to directly supply or exhaust air from the laboratory, although "transfer" of air to/from corridors may be utilized to establish required room pressurization. Negative pressurization of laboratories in relation to surrounding occupancies shall be maintained under all conditions of HVAC system and fume hood operation.

16.4.1 Exhaust Systems. Laboratory equipment utilized for personnel protection from hazardous chemical, microbiological, or radioactive airborne particles or gases shall be provided with independent exhaust systems in accordance with NFPA 99. Exhausts from general chemical laboratory fume hoods located within a laboratory unit may be combined into central exhaust systems in accordance with guidance in appropriate references. Exhausts from hoods handling perchloric acid or other strong oxidizing agents, materials or agents requiring HEPA filtration, or exhausts which, when combined, chemically interact or change the explosion/ignition limits, may not be combined. Exhaust duct discharge height shall be above the building recirculation cavity boundary. In all cases exhaust discharge shall have sufficient stack height, velocity, and distance from building openings, outside air intakes, or recirculating air currents, to preclude reentry into the building. Air velocity in exhaust ductwork shall be sufficient to transport the contaminant vapors, fumes, dusts, or other particulate matter for which the fume hood(s) is designed.

16.4.2 Laboratory Fume Hoods, General. Fume hoods shall be located in areas of minimal air turbulence, away from doors, windows, and traffic, to minimize disruption of required sash airflow. HVAC system/fume hood controls shall be designed such that operation or shutdown of any fume hood in a given space will not disrupt the required room air balance or the required sash airflow at other hoods operating in the space. General purpose laboratory fume hoods that control personnel exposure to chemicals and physical contaminants shall have a minimum sash face velocity of 0.508 m/s (100 fpm). Fume hoods shall be provided with audible and visual alarms to indicate inadequate sash airflow conditions.

16.4.3 Radioactive Material/Radioisotope Hoods. Duct systems serving hoods for radioactive material shall be constructed of acid resistant type stainless steel for their entire length. Ductwork shall be flanged with neoprene gasketed joints to facilitate dismantlement for decontamination. Fume hood exhaust shall remain in constant operation, and shall be filtered with carbon and/or HEPA filters as required to meet Nuclear Regulatory Commission (NRC) requirements. The location of filters in the

system shall be chosen to best facilitate their safe removal, disposal, and replacement by maintenance personnel. All filters shall be automatically monitored to provide indication that changeout is required. All hoods shall comply with requirements of the Nuclear Regulatory Commission.

16.4.4 Canopy Hoods for Prosthetic Dental Laboratories. Canopy hoods for Prosthetic Dental Laboratories, and exhaust ductwork extending for a distance 3000 mm (10 ft) downstream from the hood connection, shall be fabricated of material which is corrosion resistant to the caustic fumes emanating from boil-out tanks and casting activities conducted in the laboratory.

16.4.5 Biological Safety Cabinets (BSCs). Class, Type, and location of BSCs shall be as directed by the using agency. Class II BSCs are provided with HEPA filtration of recirculated air and/or building exhaust, and are provided in such areas as Microbiology and Mycology. The required open door/sash face velocity for Class I and Class II Type A BSCs shall be 0.381 m/s (75 fpm), and for Class II Types B1, B2, and B3, shall be 0.508 m/s (100 fpm). For further information of biological safety hood Class, Type, application, and exhaust requirements, refer to appropriate references.

16.4.6 Perchloric Acid Hoods. Hoods for handling of perchloric acid and other strong oxidizing agents, and the associated exhaust ductwork, shall be constructed of stainless steel. Internal water spray systems shall be provided for hood and all ductwork to facilitate the periodic washdown. Joints shall be welded and ground smooth, and all ductwork pitched back toward the hood to facilitate drainage. More detailed guidance is provided by the ACGIH publication.

16.4.7 Containment Laboratories BL-3 and BL-4. These laboratories deal primarily with indigenous or exotic agents which may cause serious or potentially lethal disease as a result of exposure by inhalation. The HVAC design for these laboratories shall assure the continuous negative pressurization and exhaust of the space. The exhaust air from these spaces shall not be recirculated to any other area of the building, but

shall be transported through dedicated exhaust ductwork to be directly discharged to the outside of the building. Design of BL-3 and BL-4 laboratory exhausts shall comply with latest editions of OSHA and other Federal regulations.

16.5 Exhaust Canopies. Exhaust canopies shall be provided for equipment or appliances generating high heat or moisture (steam) loads, such as glassware washers, boilout tanks, drying ovens, sterilizers, and stills, as required. In some cases, specially designed canopy hoods may be necessary to control personnel exposure to hazardous chemical vapors. Canopy hood design shall comply with the ACGIH data for "Canopy Hood".

16.6 Laminar Flow Clean Benches. These horizontal flow hoods shall be used in pharmacy for preparing intravenous fluids and similar laboratory processes. Clean benches recirculate room air and do not require exterior air supply or exhaust systems.

16.7 Bench-Back Slot Hoods. Slot hoods are typically built into the wall behind laboratory benches to exhaust vapors, gases, and odors that are released with little energy or velocity. Typical applications are laboratories, brace shops, and other spaces in which volatile chemicals are routinely used. Design of these hoods shall be in accordance with ACGIH guidelines, with a slot velocity of 10.2 m/s (2,000 ft/min).

16.8 Portable Bench-Top Hoods. Portable hoods with glass viewing panels and interior lighting may be used to control chemical contaminants of minor toxicity and odors. They shall be attached to built-in exhaust outlets with flexible ducts. Each built-in exhaust system outlet shall provide a minimum of 0.0755 m³/s (160 cfm) or a face velocity of 0.38 m/s (75 ft/min) at the hood, whichever provides the maximum mass flow of air. The exhaust duct opening shall be provided with a blast gate and sealing plug to stop air flow when the unit is not in service. Class II Type A BSCs shall be 0.381 m/s (75 fpm), and for Class II Types B1, B2, and B3, shall be 0.508 m/s (100 fpm). For further information of biological safety hood Class, Type, application, and exhaust requirements, refer to appropriate standards and references.

16.9 Waste Anesthesia Gas Exhaust (WAGE). In each space utilized routinely for the administration of inhalation anesthesia or analgesic agents, a Waste Anesthesia Gas Exhaust (WAGE) disposal system for removal of waste anesthetizing gases shall be provided, designed in accordance with NFPA 99. Coordinate required system vacuum pressure and terminal fittings with using Military Department Anesthesiology and Oral Surgery Departments on an individual project basis.

16.10 Medical Equipment. Use appropriate standards and practices for special ventilation requirements of medical equipment.

16.11 Ethylene Oxide. Sterilizers, aerators, manifold rooms, and disposal systems shall be directly exhausted to the outside by a dedicated exhaust system. ETO storage and supply systems and ventilation design shall be in accordance with 29 CFR 1910.1047 and the latest industry guidance. Ventilation provisions currently include such features as exhaust inlets above and below sterilizer door, waste water discharge, and floor drain. Ventilation of bottle storage rooms is also required. An audible and visual alarm shall be provided to warn of loss of airflow in the exhaust system. Increasingly, local and state regulations prohibit or limit the discharge of ETO to the environment. These shall be considered applicable to DOD medical facilities, and in such cases the design shall utilize ETO "scrubbers" or other approved technologies to prevent or reduce ETO emissions as required.

16.12 Kitchen Hoods. Exhaust hoods in the kitchen area are to be the type utilizing 80 percent unconditioned air and having an exhaust rate of not less than 0.0022 m^3 per square meter (50 cfm per square foot) of face area. Face area is defined for this purpose as the open area from the exposed perimeter of the hood to the average perimeter of the cooking surface. If economically justified, hood makeup air should consist of up to 80% outside air tempered, through heat recovery equipment, by the exhaust. Equip all hoods over the cooking service equipment with fire extinguishment systems, automatic washdown and grease extractors, and heat-actuated fan controls. Cleanout openings, and required fire protective enclosures and separations, shall be

provided in horizontal exhaust duct systems serving these hoods grease hood exhaust ducts in accordance with NFPA 96.

16.13 Pharmaceutical Admixture Rooms shall be in compliance with U.S. Pharmacopoeia (USP) 797.

17. PATIENT ISOLATION ROOM DESIGN

Isolation rooms consist of Disease Isolation and Protective Isolation rooms. The former is intended for the patient suffering from a known or suspected infectious disease, and is provided with engineering controls which assist in preventing the spread of the disease from the room. Protective Isolation rooms are provided for the patient having an immune system deficiency, and require engineering controls to assist in the protecting the patient from contamination from outside the bedroom. Rooms shall be one or the other, and not “switchable” from disease isolation to protective isolation function, or vice versa. Isolation Bedrooms shall be provided with pressure-monitoring alarms and gauges mounted on the outside corridor wall; when a central DDC control operators station is provided, the alarm should in addition be connected to that system.

17.1 Disease Isolation Bedrooms. Disease Isolation bedrooms shall be designed to incorporate requirements and guidance contained in the Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health-Care Facilities (the TB Guidelines), published in the Federal Register Vol. 59, No. 208, 28 Oct 94 (or latest edition thereof). These rooms shall be negatively pressurized and exhausted to the outside, and provided with the minimum total and outside air change rates (12/2, respectively) referenced at UFC 4-510-01. Exhaust ductwork from the bedrooms, the associated toilet, and the anteroom (if provided) shall be “dedicated” in the sense that the system may serve only the bedroom suite or other disease isolation bedrooms. This exhaust system shall be connected to the building emergency power system. Bedroom suites shall be supplied by air systems provided with constant-volume control and measuring terminal units which automatically maintain the supply air flowrate setpoint to

each space. Exhaust systems shall be constant volume systems maintaining a fixed exhaust flow rate for each space. When bedroom exhaust is located such as to prevent re-entrainment into outside air intakes or other building openings, HEPA filtration of the exhaust is not required.

17.1.1 Existing Facilities. In existing facilities, only those bedrooms designated by the facility specifically for use as Tuberculosis Isolation Bedrooms are required to be designed in accordance with the TB Guidelines referenced above. TB Isolation Bedrooms shall be negatively pressurized and exhausted, and shall be provided with 12 air changes per hour if economically or physically practicable. When not practicable to achieve this air change rate, TB Isolation Bedrooms shall have a minimum of 6 air changes per hour, to be supplemented by HEPA filter or Ultra Violet Germicidal Irradiation (UVGI) systems specifically designed for TB Room applications and providing the equivalent of an additional 6 air changes per hour. Fixed-in-place HEPA filtration units are preferable to portable units, and upper-level UVGI systems are preferred over duct-mounted units, to enhance reliability. Room exhaust shall be conducted to the outside of the building; when designed to avoid reentrainment into outside air intakes or other building openings, HEPA filtration of the exhaust is not required.

17.1.2 Isolation Suite Relative Pressurization. When an anteroom is provided for the isolation bedroom, interposing between the bedroom and corridor to provide a “buffer” airspace for additional protection, there are several recognized design approaches for corridor-anteroom-bedroom relative pressurization. A recommended design is to provide for the anteroom to be under negative pressure relative to the corridor, and positively pressurized relative to the bedroom.

17.2 Protective Isolation Bedrooms. The air supply to the protective isolation bedroom suite shall be constant flow and shall be provided with HEPA filtration. 12/2 total and outside air changes, respectively, are required for these bedrooms. As with disease isolation bedrooms, there are several recognized approaches to the relative

corridor-anteroom-bedroom pressurization; a recommended approach is to establish the anteroom positively pressurized relative to the corridor, and negatively pressurized relative to the bedroom.

17.2.1 Existing Facilities. When upgrading existing protective isolation bedrooms to this criteria, 12/2 air changes per hour shall be provided if economically and physically practicable. When impractical, these bedrooms shall be provided with a minimum of 6 total air changes per hour and supplemented by HEPA filtration or UVGI systems to provide the equivalent of 12 air changes.

17.3 Disease Isolation Exam or Waiting Rooms. Disease isolation exam or waiting rooms shall be provided with a minimum of 12 total air changes, as provided in UFC 4-510-01, with the room air exhausted to the outside.

18. REFERENCES

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Handbook Series.

ACGIH, "Manual of Recommended Practices for Industrial Ventilation."

NFPA 99, "Standard for Health Care Facilities."

NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilation System."

NFPA 96, "Cooking Equipment, Vapor Removal."

NFPA 801, "Facilities for Handling Radioactive Materials."

NFPA 45, "Labs Using Chemicals".

NFPA 101, "The Life Safety Code".

UFC 3-400-02, "Design: Engineering Weather Data"

ASHRAE 15, "Safety Code for Mechanical Refrigeration".

ASHRAE 34, "Number Designation and Safety Classification of Refrigerants".

SMACNA, "HVAC Duct System Design".

NFPA 70, "National Electrical Code".

UL 181, "Standard For Safety, Factory-Made Air Ducts".

ASTM C 665, "Mineral-Fiber Blanket Thermal Insulation". 8s.

ASHRAE 62.1. "Ventilation for Acceptable Indoor Air Quality" American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

OSHA - Part 1910, "Occupational Safety and Health Standards."

CDC-NIH, "Biosafety in Microbiological and Biomedical Laboratories."

Standard 49, "Class II (Laminar Flow) Biohazard Cabinetry", National Sanitation Foundation.

ANSI/EIA/TIA-569-A Standard Commercial Building Standard for Telecommunications Pathways and Spaces

UFC 4-010-01, "DoD Minimum Antiterrorism Standards for Buildings"

UFC 3-600-01, "Fire Protection Engineering for Facilities"

UFC 4-510-01, "Design: Medical Military Facilities"

U.S. Pharmacopoeia (USP) Pharmacists' Pharmacopoeia General Chapter 797, Pharmaceutical Compounding — Sterile Preparations.