UFC-3-400-10N
July 2006
Including Change 1, March 2012

UNIFIED FACILITIES CRITERIA (UFC)

MECHANICAL ENGINEERING

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

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UNIFIED FACILITIES CRITERIA (UFC)

MECHANICAL ENGINEERING

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	Date:	Location
1	March 2012	Minor changes throughout document

\1\ This UFC supersedes UFC 3-410-02N, dated 8 June 2005 and UFC 3-400-10N (DRAFT), dated July 2006. /1/

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the 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 Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Center for Engineering and the Environment (AFCEE) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

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

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

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Document: UFC 3 400-10N, *Mechanical Engineering*
Superseding: None.

Description: This UFC 3-400-10N provides mechanical engineering design and analysis criteria for design-build and design-bid-build projects.

Reasons for Document:

- Provide technical requirements for mechanical systems design criteria.
- The Design-Build processes as defined herein reflect current contract requirements.
- Define minimum requirements for contract documents in terms of drawing types and content, and specification information.

Impact: There are negligible cost impacts. However, the following benefits should be realized.

- Promotes the use of and moves the DoD toward more efficient commercial model codes and standards.
- Standardized guidance has been prepared to assist environmental engineers in the development of the plans, specifications, design analyses, and Design/Build Request for Proposals (RFP).
- This guidance has been prepared along with updates to the associated Performance Technical Specifications and Engineering Systems Requirements documents. The three types of documents have been aligned to allow improved consistency in the preparation of project requirements.

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TABLES

CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

The purpose of this document is to provide technical guidance and outline technical requirements for the more typical aspects of the mechanical engineering portion of Architect/Engineer (A/E) contracts for the Naval Facilities Engineering Command (NAVFAC). The information provided in this guide shall be utilized by mechanical designers in the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFP) and shall serve as the minimum mechanical design requirements. Project conditions may dictate the need for design that exceeds these minimum requirements.

1-2 APPLICABILITY.

This document is applicable to the traditional mechanical services customary for Design-Bid-Build construction contracts and for Design-Build construction contracts.

1-3 REFERENCES.

Appendix A contains the list of references used in this document. Furthermore, this document references UFC 1-200-01, *General Building Requirements*, except as modified herein.

1-4 COMMUNICATIONS.

Direct communication with the government's project manager and mechanical reviewer is encouraged. This may avoid unnecessary re-submittal of plans and specifications due to a misunderstood comment. The reviewer's name, phone number and email address can be found on the comment sheets.

1-5 ADDITIONAL REQUIREMENTS.

Local and regional requirements may differ from those included herein. Contact the Government Project Manager for guidance.

1-6 PERMITS: CONSTRUCTION, ENVIRONMENTAL & OTHER.

Obtain the permits necessary for environmental, construction and operation of facilities. Pay any fees associated with each permit. \1\/1/

CHAPTER 2 REQUIREMENTS

2-1 ENERGY SUPPLY

2-1.1 Fuel Source and HVAC System Selection.

New facilities and facilities undergoing major and minor renovation as defined in UFC 3-400-01, *Energy Conservation*, are required to be analyzed to determine the most cost effective and practical fuel source(s) and heating and cooling system types. Provide energy analysis in accordance with UFC 3-400-01.

2-1.2 Energy Conservation.

\1\ Provide mechanical systems based on lowest life cycle cost of the approved alternatives. Include a comprehensive estimate of system maintenance costs in the analysis. Provide documentation to support compliance in accordance with Chapter 3 requirements. /1/

\1\/1/

2-1.3 Energy Star.

\1\All HVAC equipment, appliances, related electrical equipment, and water saving fixtures shall meet or exceed the minimum efficiencies listed by Energy Star, EPA "Watersense" Program or the Federal Energy Management Program (FEMP). The FEMP website lists all Energy Star and FEMP rated products and provides recommended efficiencies and life cycle data. The FEMP energy-efficient product website is at http://www1.eere.energy.gov/femp/technologies/procuring_eeproducts.html. The EnergyStar website is at http://www.energystar.gov./1/ For product groups where Energy Star labels are not yet available, select products that are in the upper 25% of energy efficiency as designated by FEMP.

2-1.4 Sustainable Design.

Integrate sustainable development principles into the mechanical system selection and design. \1\Refer to UFC 4-030-01, *Sustainable Development,*/1/ and utilize the U.S. Green Building Council's LEED Green building Rating System as a tool to apply sustainable development principles and as a metric to measure the sustainability achieved through the planning, design, and construction processes.

2-1.5 Indoor Environmental Quality and Mold.

Provide outside air ventilation as prescribed by \1\ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*./1/ Consider the factors of "Multiple Spaces", "Ventilation Effectiveness", and "Intermittent or Variable Occupancy" as specified in \1\ASHRAE Standard 62.1./1/ The building and mechanical system must be designed and constructed to prevent the growth of mold. Refer to UFC 3-800-10N, *Environmental Engineering for Facility Construction*, for additional information and requirements. Air Force facilities must comply with AF ETL 04-3.

2-1.6 **Humid Areas.**

All heating, ventilating and air conditioning designs in humid areas must comply with the requirements of the Interim Technical Guidance FY05-02, *NAVFAC Humid Area HVAC Design Criteria*. Humid areas are defined in paragraph 5-1.4 of the Interim Technical Guidance.

2-1.7 **Economizer Cycles.**

\1\Air side economizer cycles shall be provided when required by ASHRAE Standard 90.1, *Energy Standards for Buildings Except Low Rise Residential Buildings*. If air side economizers are not required by ASHRAE, follow the requirements of Interim Technical Guide FY05-02. /1/

2-1.8 **Building Pressurization.**

Maintain the building under a positive pressure \1\of 0.05"/1/ in order to negate infiltration.

2-2 **HEAT GENERATING SYSTEMS**

2-2.1 **Boilers.**

Install boiler(s) and associated hot water pumps in a mechanical room inside the facility unless otherwise noted in the Project Program. Passageways around all sides of boilers shall have an unobstructed width of 1 meter (3 feet), or the clearances recommended by the boiler manufacturer, whichever is greater.

2-2.1.1 **Multiple Boilers.** In multiple boiler installations, the lead boiler should operate up to full capacity prior to starting the next boiler. During heating season, multiple boilers should be kept warm and ready should the lead boiler fail to operate.

2-2.1.2 **Boiler Procurement.** DoD policy requires that boilers procured be ASME certified.

2-2.1.3 **Boiler Emissions.** Boilers must comply with regulatory requirements under the Clean Air Act regarding Title V and New Source Review permits programs as well as requirements under New Source Performance Standards and National Emissions Standards for Hazardous Air Pollutants (NESHAP). Contact the local or regional Public Works Department or Base Civil Engineering Branch for specific requirements.

2-2.1.4 **Draft Hoods.** Provide for each gas-fired piece of equipment, except power vented and condensing type equipment.

2-2.1.5 **Barometric Dampers.** Provide barometric dampers for all boilers requiring negative draft.

2-2.2 **Steam Boilers.**

On boiler start-up, the condensate in a gravity system may not return quick enough to maintain the boiler water level. Contact the boiler manufacturer for boiler feed system tank size and location.

2-2.3 **Condensing Boiler Systems.**

Provide hydronic systems with condensing gas-fired boilers with a water volume equal to five (5) minutes of water flow through the system pump (minimum), or as required by the boiler manufacturer. This insures there is sufficient water volume to prevent short cycling of the burner. If there is insufficient water volume, an inertia tank must be installed to attain the minimum system volume required. Non-condensing boilers do not require this minimum.

2-2.4 **Combustion Air.**

Provide combustion air for gas and oil-fired equipment in accordance with International Mechanical Code (IMC) and NFPA requirements.

2-2.5 **Steam Heating.**

Steam heat should not be used except on rehabilitation projects where budget constraints preclude conversion of an existing steam heating system to hot water.

2-2.6 **Infra-Red Gas Radiant Heaters.**

When using non-condensing gas infrared heaters, the length of the exhaust flue should be minimized. To minimize condensation, run the flue horizontally with a slight pitch down from the heater to a sidewall exit. Heaters should 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. Consider condensing type IR heaters for larger applications. \1\Provide ducted combustion air intake through roof or exterior wall. Direct vent condensing type IR heaters to carry water vapor and exhaust out of the building./1/

2-3 COOLING GENERATING SYSTEMS

2-3.1 **Condensing Temperatures.**

The design condensing temperature for air-cooled condensers, chillers, etc must be ambient design temperature plus 2.8 degrees C (5 degrees F

2-3.2 Chilled Water Systems.

Chiller manufacturers recommend minimum system volumes to prevent short-cycling of the chiller(s) to promote long chiller life and good chilled water temperature control, especially in smaller chilled water systems. In small systems it may be necessary to install an inertia tank in the chilled water loop to achieve the required minimum system volume. Check the requirements of the chiller manufacturer and provide an insulated, inertia tank of sufficient volume when required. Install the chilled water \1\inertia/1/ tank downstream of the chiller and upstream of the cooling coils. Provide calculations to demonstrate compliance with this requirement. Volumes for components may be estimated where manufacturer's data is not available.

2-3.3 Chillers.

When multiple chillers serve a common central chilled water system, install a flow control balancing valve on the leaving side of the chilled water and condenser water (where applicable) of each chiller. Flow orifices with butterfly valves should be provided for larger pipe sizes. On multiple chiller systems, design pumping and piping systems to prevent water flow through chillers that are not in operation. \1\Avoid the use of reciprocating compressors. Use screw compressors whenever possible or multiple scroll compressors with an unloading capability down to 25%./1/ Utilize roof mounted chillers only as a last resort. If located on the roof, mount the chiller on a steel skid with isolators supported from the structural roof framing.

2-3.4 Cooling Towers.

Provide a butterfly or 3-way diverting valve in the by-pass line for all cooling towers that are specified to have a condenser water by-pass for regulating the condenser water supply temperature. Provide automatic isolation valves on inlet and outlet of each cell for multi-cell or multi-tower applications. Size condenser water flow to chiller for the design flow rate, not the oversized tower flow rate. Cooling tower piping shall by-pass to the cooling tower's sump.

2-3.5 Ground-Coupled Heat Pump (GCHP) System Design \1\/1/

\1\The requirements that follow are intended to complement the requirements of ASHRAE and recognized consortiums, such as the International Ground Source Heat Pump Association (IGSHPA). /1/ Nonresidential, commercial scale ground source heat pump systems require the utilization of computer design software. Such software should consider the interaction with adjacent loops and long-term buildup of rejected heat in the soil.

2-3.5.1 Provide a bypass line around the condenser of each heat pump unit to facilitate flushing and purging the condenser loop without subjecting the condenser coil to residual construction debris.

2-3.5.2 Provide isolation valves and valved tee connections for flushing and purging of the well field independently from the building condenser water system.

2-3.5.3 Do not provide automatic water makeup in residential GCHP systems. Reserve the added complexity and cost to larger, non-residential systems of 10 tons or larger. Utilize cupronickel refrigerant-to-water heat exchangers in open condenser loops only.

2-3.5.4 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.

2-3.5.5 Utilize reverse return headers in large well fields. For heat pumps with reduced flow requirements of 2 GPM/ton or less, consider series return in order to maintain fluid velocities necessary to foster good heat transfer. Base the decision to commit to reverse return on installed cost, pumping costs and the system flow requirements. Consult ASHRAE and IGSHPA Design documentation for additional information.

2-3.5.6 Regulatory requirements for vertical wells vary widely among States. Some regulations require partial or full grouting of the borehole. The State of Virginia, for example, requires bentonite or cement grout seals in the top 6.1 meters (20 feet) of a borehole; while North Carolina requires a full depth seal. A full depth bentonite seal, however, is not necessary; the wells in N.C. may be grouted with cement mixed with soil from the bore drilling. Confirm with the Government Project Manager and consult current state and federal regulations, as well as relevant building codes.

2-3.5.7 The thermal conductivity of grouting materials is typically low when compared to the conductivity of native soils. Grout acts as an insulator and will, thus, hinder heat transfer to the well field. When governing regulations permit, consider the following alternatives:

a. Reduce the quantity of grout to an absolute minimum. Fine sand may be used as backfill where permitted, but caution must be exercised to ensure the interstitial space between pipe and borehole is filled to enhance conductivity.

b. Utilize thermally enhanced grout. Consult ASHRAE, *Commercial/Institutional Ground-Source Heat Pump Engineering Manual*. Reduce the borehole diameter as much as possible to reduce the insulating effects of grout or backfill.

2-3.5.8 In geographic areas with heating dominated climates, an antifreeze solution may be required if condenser loop temperatures are expected to drop below 5 degrees C (41 degrees F). Avoid use of antifreeze, but if necessary, keep concentrations to a minimum. Utilize condenser water circulating pumps with high efficiency motors. Design them to operate near their peak of maximum efficiency.

2-3.6 **Refrigerants.**

The use of Ozone Depleting Substances (ODS) as well as the qualifications and credentials of personnel servicing equipment that contains ODS is restricted.

\1\Refrigerants shall have an Ozone Depletion Potential (ODP) no greater than 0.0 with the exception of R-123, which will continue to be produced until 1 January 2020 and will remain acceptable for installation in DoD facilities until then. On 1 January 2020, R-123 will no longer be allowed. The ODP shall be in accordance with the "Montreal Protocol on Substances That Deplete the Ozone Layer", September 1987, as amended through 2008, sponsored by the United Nations Environment Programme./1/

2-3.7 **Refrigerant Piping.**

Avoid refrigerant piping runs longer than 15 meters (50 feet) unless specifically allowed by the equipment manufacturer. Size refrigerant piping in accordance with the manufacturer's recommendations.

2-4 **DISTRIBUTION SYSTEMS**

2-4.1 **Air Distribution.**

2-4.1.1 **Air Change.** The quantity of supply air shall be sufficient to provide a minimum of four air changes per hour within the conditioned space. If the supply air quantity determined from the sensible cooling load does not provide four air changes, room air may be mixed with conditioned air in a fan-powered terminal to increase the quantity of supply air. Use a maximum ceiling height of 3.1 meters (10 feet) when calculating air changes per hour. \1\ Do not use self-modulating air diffusers./1/

2-4.1.2 **Locker Room HVAC Systems.** \1\Locker room ventilation shall be designed in accordance with ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*./1/ Draw conditioned air into locker rooms from adjacent spaces, and provide additional supply air as required. This uses the outside air required for human occupancy in the adjacent spaces for secondary air conditioning of the locker space and maintains locker spaces at a negative pressure with respect to adjacent spaces. \1\Do not exhaust showers through adjacent spaces. Provide aluminum exhaust grilles inside the shower area./1/

2-4.1.3 **Closets in Bachelor Housing (BH).** BH facilities shall be designed in accordance with UFC 4 721-10, *Navy and Marine Corps Bachelor Housing*. In Humid Areas, provide a Dedicated Makeup Air System 100% outside air supply register in each clothing closet in new BH modules, sized to provide approximately 7.5 L/s (15 CFM) for humidity control.

2-4.1.4 **Outside Air Ducts.** \1\Provide a means of determining outside air flow amounts by measurement or calculation. If an air flow measuring station is provided in the outside air duct, the equipment layout shall allow for the straight duct length and size requirements of the air flow measuring station in accordance with the manufacturer's recommendations./1/

2-4.1.5 **Variable Speed Drives.** Select system equipment to deliver design flows so that maximum operational flexibility is maintained. Verify fan performance at minimum and maximum operating points.

2-4.1.6 **Vibration and Noise Isolation.** Where vibration and/or noise isolation is required, provide a vibration isolator schedule on the drawings indicating type of isolator, application, and deflection in mm (inches).

2-4.1.7 **Access Panels.** Provide access panels in floors, walls, and ceilings (except in lay-in tile applications) as required to access valves, smoke dampers, fire dampers, balancing dampers, balancing valves, air vents, drains, duct coils, filters, \1\air flow monitoring stations,/1/ equipment, etc. Indicate location and size on drawings. Verify that the dimensions will yield reasonable accessibility.

2-4.1.8 **Equipment Supports.** Provide for vibration isolation where required and schedule the vibration isolation components on the drawings. Coordinate with and provide hardware required to meet Anti-terrorism requirements in UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings,* and seismic requirements in accordance with UFC 1-200-01, *General Building Requirements*. All equipment mounted on a roof must be fastened to the building as recommended by the structural engineer, \1\and must be in compliance with all applicable code provisions for high wind protection./1/.

2-4.1.9 **Space Noise Levels.** Design and install systems to maintain noise levels below those recommended in the ASHRAE Handbooks.

2-4.1.10 \1**Variable Air Volume (VAV) HVAC System Design /1/**

\1\ The requirements that follow are intended to complement the requirements of ASHRAE. /1/

2-4.1.10.1 Do not oversize the system. Do not add safety factors in the load calculations. Safety factors not only have the ramification of added cost, but also penalize the system during frequent part load conditions commonly experienced in humid, coastal locations.

2-4.1.10.2 Utilize computerized load calculations based on the ASHRAE Transfer Function Method. Select all central air handling equipment and central plant equipment for "block" loads. Spread diversity through the supply ducts, taking full diversity at the air handling unit, and lessening diversity when moving away from the air handling unit toward the VAV terminal units, until no diversity is taken at the distant VAV terminal run outs.

2-4.1.10.3 Design for both peak and part load conditions (minimal wall transmission load, low occupancy, etc.). VAV Systems shall provide acceptable air circulation and proper outside air for all conditioned spaces regardless of the loading conditions.

2-4.1.10.4 Address the psychrometric performance of the cooling coils, with full consideration of the method of capacity control and its limitations, during part load conditions when the sensible heat ratio can be significantly reduced. Submit part load design calculations. Check the fan operating characteristics throughout the range from the minimum to the maximum flow conditions that will be experienced. Evaluate the off-peak turndown requirements for the main air handler VAV fan. Do not utilize discharge dampers or inlet vanes for air flow modulation. Provide variable frequency drives for air volume modulation.

2-4.1.10.5 Design a positive means of maintaining ventilation rates during part load conditions. Select the minimum primary air requirements of the VAV terminal units to maintain at least the minimum outside air ventilation requirements. The Direct Digital Control (DDC) system shall comply with the requirements of \1\ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*,/1/ for polling of boxes to maintain proper ventilation levels. Provide an air flow monitoring station in the outside air duct controlling the outside and return air dampers or a constant volume outside air fan to maintain the minimum outside air requirements. \1\/1/When using airflow measuring stations (AFMS) for monitoring and maintaining constant outside air ventilation rates, avoid placement of the AFMS in the outside air duct unless a minimum of 12 duct diameters of straight duct downstream of the outside air louver can be provided \1\unless the manufacturer allows a smaller distance./1/ Turbulence generated by the outside air intake louver will generate high turbulence and a highly unstable control loop. For large systems using a constant air volume (CAV) fan use a pressure independent velocity controller in the outdoor air intake to keep outdoor airflow constant as the VAV air handler fan modulates. Provide a low velocity filter module upstream of the air injection fan to prevent dust/dirt build up that may clog the pitot tubes associated with the volume regulator. Provide a duct access door at the inlet to the CAV terminal box for periodic inspection and cleaning.

2-4.1.10.6 Utilize the static regain method in design of the supply ductwork. Design return ductwork using the equal friction method. \1\Use hard ducted returns to the main air handler./1/

2-4.1.10.7 Provide control for a constant cooling supply air temperature. Resetting the supply air temperature upwards increases the coil sensible heat ratio and results in elevated space relative humidity.

2-4.1.10.8 Provide electronic controls; pneumatic controls present problems with repeatability and maintenance.

2-4.1.10.9 Locate the static pressure sensor for modulating fan capacity two-thirds to three-quarters the distance from the supply fan to the end of the main trunk duct. Locate in straight run of ductwork. Provide static pressure reset in accordance with ASHRAE Standard 90.1, *Energy Standards for Buildings Except Low Rise Residential Buildings*. Provide protection against over pressurization of the supply duct system. Utilize pressure independent (PI) terminal units. Do not use light troffer return units. Light troffers reduce room sensible loads with undesirable effects on room air changes and outdoor ventilation distribution. Control the cooling coil capacity, especially in the more humid climates. VAV is inherently one of the best of the chilled water systems for air conditioning in tropical climates.

2-4.1.10.10 Do not utilize DX VAV systems without prior approval of the Government Project Manager. Direct expansion equipment shall be specifically designed and manufactured for VAV applications. The same manufacturer shall provide central air handling units, VAV boxes/zone dampers and zone controls. Airflow through the evaporator coils shall not be modulated. Provide duct mounted zone control damper units with integral control box, designed for use with DX VAV packaged systems.\1\/1/

2-4.1.10.11 Provide round or flat oval duct systems for primary air on all VAV supply systems. Utilize round ducts wherever space availability permits.

2-4.1.10.12 Proper VAV box primary air entry conditions are critical for achieving stable, accurate airflow delivery. Every effort must be made to avoid high turbulence in the proximity of the VAV terminal flow sensor. Design the primary air duct branches to the VAV terminals with a straight duct section of at least 6 to 8 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 aforementioned straight duct section.

2-4.1.10.13 Primary air connections to VAV terminals should always be with a rigid duct. If a section of flexible duct, or a flexible connection, is required for vibration control, limit the length to no more than 305 mm (12 inches), and ensure that it is placed at least 6 to 8 duct diameters upstream of the VAV box collar connection/flow sensor.

2-4.1.10.14 VAV terminal boxes have minimum primary air velocity limitations imposed by the volume regulators utilized. Though many manufacturers claim their VAV boxes can deliver minimum primary air at flow rates resulting in inlet velocities of 189 L/s (400 fpm) and a velocity pressure of 2.48 Pa (0.01 inch w.g.), the lack of a certifying agency to test the manufacturer's claims support a more conservative approach. Minimum primary airflow rates shall be established to attain minimum velocity pressures of no less than 7.45 Pa (0.03-inch w.g.). Do not utilize system-powered (also called "pressure dependent") terminal units.

2-4.1.10.15 Special consideration must be given when fan-powered VAV boxes are specified and when it is necessary to specify a VAV box fan CFM in excess of the specified maximum primary air CFM. When used with a dropped ceiling return plenum, the excess VAV box CFM will introduce secondary air into the conditioned space. This has the effect of transferring return side coil cooling loads to room-side sensible loads. Always make sure the transferred sensible heat is taken into account in the calculated room-side sensible heat. Failure to do so may result in inadequate primary airflow rates to satisfy the room sensible heat loads.

2-4.1.10.16 Discharge dampers shall be installed \1\in the supply duct from/1/ all series fan-powered VAV boxes (SFPVAV), regardless of the type of fan speed control utilized (3-speed fan switch or solid state speed control).

2-4.1.10.17 When it is necessary to install VAV terminals at high elevations above finished floors, service and maintenance accessibility must be carefully analyzed. Where mounting heights are in excess of 3.6 m (12 feet) above finished floors, special accommodations are necessary:

a. Do not use fan-powered VAV boxes in such locations, since there are many serviceable components involved. Instead, consider using non fan-powered terminal boxes for use in high mounting height locations to eliminate the need for fan servicing and filter change access.

b. When DDC controls are installed, \1\specify the location of the DDC digital controller to facilitate ease of access./1/

c. If scaffolding, scissor lifts, ladders or other means is required to access VAV units, special considerations must be made. Be sure clear floor area is available below the VAV boxes to facilitate the means of access (i.e. scaffolding, etc) and in an area that will be likely to remain clear of permanent or semi-permanent equipment or furnishings.

d. \1\/1/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. The means to monitor VAV box function will maximize the means to troubleshoot remotely, thus reducing the frequency for above ceiling access by maintenance personnel.

e. \1\/1/

f. 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.

2-4.1.10.18 Fan-powered VAV terminal boxes can be noisy. Perform an acoustic analysis to ensure designs are within acceptable NC criteria noise levels. Pay particular attention to noise attenuation in locations where the boxes are installed in spaces without dropped ceilings. Analyze potential for sound breakout from main supply air ducts. Provide attenuation as required. Do not provide acoustical duct liner for attenuation.

2-4.1.11 **Duct Lining.** \1\Acoustic duct lining shall not be used except for air transfer ducts. Use double wall acoustic duct where sound attenuation is necessary. Increase the outside duct dimensions as required to maintain adequate internal cross sections./1/

2-4.1.12 **Fire Dampers.** Provide fire dampers and access panels in ductwork penetrating fire rated walls and floors in accordance with NFPA 90A.

2-4.1.13 **Flexible Connections.** Provide flexible connections in ductwork at equipment. Support duct at flexible connections to ensure proper alignment.

2-4.1.14 **Flexible Duct.** \1\Flexible duct lengths shall not exceed \1\1.5 m (5 feet). Do not use flexible duct for offsets greater than 45 degrees or connections to diffusers registers or grilles greater than 45 degrees./1/

2-4.1.15 **Louvers.** Provide rain or storm proof louvers at wall intakes and exhausts. Indicate dimensions, airflow rate, and air pressure drop. Consider the potential for carry-over of wind driven rain.

2-4.1.16 **Screens.** Provide insect or bird screens, as applicable, at all building intakes and exhausts.

2-4.1.17 **Door Louvers.** Size for minimal pressure drop.

2-4.2 **Water Distribution.**

2-4.2.1 **Variable Speed Drives.** Select system equipment to deliver design flows so that maximum operational flexibility is maintained. Verify pump performance at minimum and maximum operating points.

2-4.2.2 **Chilled Water \1\and Condenser Water/1/ Pumps.** Provide a dedicated primary pump and condenser water pump for each chiller. Provide piping and valve configuration that allows each chiller to operate with any primary pump and with any condenser water pump. Provide back-up or standby pumps so that the total system capacity is available with any one pump out of service.

2-4.2.3 **Hot Water Pumps.** Provide back-up or standby pumps so that the total system capacity is available with any one pump out of service.

2-4.2.4 **Piping systems.** \1\On variable flow systems, maintain a minimum system flow of 20-30% of peak flow to avoid pump dead-head and overheating. /1/

2-4.2.5 **Pressure and Temperature Taps.** Provide pressure and temperature taps ("Pete's Plugs") on the inlets and outlets of all coils, pumps, chillers, heat exchangers, and other equipment.

2-4.2.6 **Expansion and Compression Tanks.** Utilize diaphragm type expansion tanks. Size the expansion tank according to the latest edition of the ASHRAE Systems Handbook. Indicate the acceptance volume, nominal dimensions, configuration (i.e. horizontal or vertical) and pre-charge air pressure.

2-4.2.7 **Expansion Loops and Devices.** Provide expansion loops and/or 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 utilize geometry and ball joints where possible.

2-4.2.8 **Cold Water Make-up.** Provide for make-up to each water system. Provide pressure gauges up and downstream of the PRV. Provide bypass line with a globe valve for each PRV. Provide hose bibbs in the make-up water line to cooling towers and evaporator condensers for washdown of equipment.

2-4.2.9 **Drain Lines.** Provide drain lines from air handling units, fan coil units, \1\pressure relief valves, backflow preventers,/1/ etc. Provide a water seal on drains as required. Terminate condensate drain lines in accordance with the IMC \1\and NAVFAC environmental policy when routing to storm drain or sanitary sewer./1/.

2-4.2.10 **Backflow Preventers.** Backflow preventers are required at all connections to the potable water system in accordance with the IPC.

2-4.2.11 **Chemical Feeders.** Fill openings should be no higher than 1.2 meters (4 feet) above the finish floor for ease of filling.

2-4.2.12 **Air Vents.** Provide in locations as required in the IMC. Provide manual type vents where possible. Use of automatic air vents is discouraged and should be minimized. Pipe the drains from automatic vents away from concealed areas for visual inspection and to prevent damage to ceilings, etc. Provide manual shut-off valves or stop-cocks for automatic air vents.

2-4.2.13 **Drain Valves.** Provide drain valves at all low points in piping systems. Pipe drain valves to floor drains where possible. Where not possible, provide hose connection.

2-4.2.14 **Check Valves.** Provide check valves to prevent backflow and at the discharge of most pumps. When used in drain lines, verify sufficient head to open flap to regain flow. Provide non-slam type on high head applications. Provide damping type on air compressor discharges. \1\"Triple duty" or "multi purpose" valves which combine a check valve, throttling valve, and shut-off valve shall not be used in piping systems./1/

2-4.2.15 **Freeze Protection.** Design pipe temperature maintenance systems (i.e. heat trace) to the lowest recorded temperature in UFC 3-400-02, *Engineering Weather Data*.

2-4.2.16 **Underground Piping Systems.** Underground piping systems for steam, condensate and chilled and hot water must be factory-prefabricated, pre-insulated, and direct bury type. The Underground Heat Distribution System manufacturer is the company responsible for the design and manufacture of the pre-engineered system. The manufacturer directs the installation of their system, and provides a representative on the job site.

2-4.2.17 **Legionella Disease.** Design waterside systems to avoid potential exposure to Legionella Disease.

\1\2-4.2.18 **Pump Insulation.** Provide two-piece metal, closed cell insulated, removable insulation boxes for all pumps. /1/

2-4.3 **Building Exhaust System.**

Provide exhaust system for removal of heat, fumes, dust, and vapors in various spaces in accordance with ASHRAE. If natural ventilation is proposed, provide calculations to support its use as a reliable means of ventilation. \1\Exhaust openings shall located to provide the clearances required by chapter 5 of the IMC./1/

2-4.3.1 **Equipment Room Ventilation.** Provide mechanical and electrical equipment rooms with 10 air changes per hour or an exhaust rate to limit room temperature rise to 5.6 degrees C (10 degrees F) above the outdoor summer design dry bulb, whichever is greater. Ventilate equipment rooms with a thermostatically controlled exhaust fan, and a weather tight inlet air louver or hood. To ensure that equipment rooms containing combustion burners for boilers, water heaters, or furnaces do not operate as negative pressure areas, utilize supply fans rather than exhaust fans for ventilation. For design heating temperatures less than 4.4 degrees C (40 degrees F), provide motor operated, normally closed dampers at air inlet and exhaust openings. Equipment rooms containing refrigeration equipment shall be ventilated in accordance with IMC and ASHRAE Standard 15.

2-4.3.2 **Exhaust/Intake Locations.** Provide adequate separation between outside air intakes and exhaust outlets, waste vents and boiler stacks. Consider prevailing winds and force protection requirements. Outside air intakes must be 3.0 m (10 ft) minimum above ground elevation to satisfy Anti-Terrorism (AT) requirements.

2-4.3.3 **Roof Fans.** Roof exhaust fans should be avoided due to maintenance access restrictions and roof leak potential. If provided and where feasible, utilize direct drive fan motors with speed controllers to reduce maintenance requirements.

2-4.4 **Fire Station Diesel Exhaust.**

Provide an engineered fire apparatus exhaust removal system. Refer to Interim Technical Guide (ITG) # FY00-06 for additional information. The system should include an overhead sliding track mechanism to permit a flexible exhaust hose to travel with the fire apparatus into and out of the apparatus bays. The fire apparatus exhaust hose shall automatically disconnect from the vehicle as it exits the bay.

2-4.5 **Maintenance Bay Vehicle Exhaust.**

Provide an engineered vehicle exhaust removal system. The system shall include an overhead or under floor system. Overhead ductwork system shall be provided with a retractable flexible exhaust hose to travel from the vehicle exhaust into and out of the ductwork. The exhaust fan for all systems shall be specifically designed and manufactured for vehicle exhaust.

2-4.6 **Kitchen (Galley) HVAC Systems.**

Check project documentation to determine if air conditioning of kitchens is allowed. No air shall be returned from the kitchen to the HVAC system. Design dining facilities in accordance with UFC 4-722-01, *Dining Facilities,* and so that air flows from dining areas to kitchen areas to provide make-up air for kitchen exhausts. Maximize the use of dining area make-up air to the kitchen as this will provide secondary cooling for the kitchen staff. If additional make-up air is required for kitchen exhausts, provide push-pull kitchen hoods with built-in heated make-up air supply. Design kitchen hoods in accordance with UFC 4-722-01, *Dining Facilities*. \1\Consider variable speed, demand controlled kitchen hoods for larger systems./1/ Kitchen hoods with built-in make-up air shall be of the horizontal face discharge type. "Short circuit" hoods are prohibited. Provide control interlocks for supply and exhaust fans to ensure that the HVAC system balance is maintained and that the proper direction of airflow is maintained during normal operations. Do not utilize evaporative coolers on kitchen supply air in humid areas. The increased humidity of the ventilation air will negate any small cooling affect. Provide fire suppression system for hoods in accordance with UFC 3-600-10N, *Fire Protection Engineering*.

2-4.7 Industrial Ventilation Systems

2-4.7.1 **General.** Design industrial ventilation systems in accordance with the latest edition of *Industrial Ventilation, A Manual of Recommended Practice*, published by American Conference of Government Industrial Hygienists (ACGIH). For Navy projects, also comply with UFC 3-410-04N, *Industrial Ventilation*. Air Force projects shall comply with AFOSH Standard 161-2.

2-4.7.2 **Design Guidelines.** Research the process or operation before design starts (i.e. find out contaminants, toxicity, process temperature, etc.).

2-4.7.3 Provide hoods designed for effective capture of contaminants while minimizing air flow for energy conservation. Do not specify or provide a canopy hood unless process is nontoxic.

2-4.7.4 Specify the appropriate fan for the application. When selecting a fan, consider noise generation, material handled through the fan (e.g., corrosives, flammables, etc.), and future expansion or flexibility of the system.

2-4.7.5 Provide tempered make-up air for all ventilation systems. Ensure that make-up air does not cause turbulence at the exhaust hood. Interlock make-up air fan to exhaust fan. Do not recirculate exhaust air.

2-4.7.6 Provide an offset discharge stack, with drain, for exhaust systems. Do not utilize a "conical cap" exhaust stack. Provide at least 7.5 m (25 feet) between exhaust outlets and outside air inlets to prevent circulating contaminated exhaust air back into the building.

2-4.7.7 Provide an air cleaning device when required by state and federal regulations. Obtain clear guidance and direction from the Government Project Manager. Select air cleaning devices that will maximize contaminant removal and ease of maintenance while minimizing cost.

2-4.7.8 Provide air flow and static pressure calculations with each design following the methods in the latest edition of the ACGIH Ventilation Manual.

2-5 TERMINAL & PACKAGE UNITS

2-5.1 System Selection Criteria.

Do not utilize room fan coil units or packaged terminal units, such as individual through-wall heat pumps, for facilities such as office buildings and Bachelor Quarters or for any facility larger than 465 square meters (5000 square feet), unless conditioned make-up air is provided to each space through a central, continuously operating, dedicated make-up air system. Conditioned make-up air shall be ducted to each room or to the return side of each fan coil or terminal unit.

2-6 CONTROLS & INSTRUMENTATION

2-6.1 General Controls.

Provide the simplest HVAC controls that will accomplish the intended function.

2-6.2 Control Dampers.

Provide parallel blade dampers for two-position, on/off control. Provide opposed blade dampers for modulating applications, but for best performance, their pressure drop should be between 5% and 20% of the total system pressure drop. They are effective for two-position, on/off applications as well, but are more expensive than parallel dampers.

2-6.3 Carbon Monoxide Detectors.

In Family Housing containing fuel-fired appliances, provide UL 2034 listed, line voltage operated, residential carbon monoxide (CO) detectors. Detectors shall feature digital readout and shall be located and installed in accordance with the manufacturer's instructions.

2-6.4 DDC Systems.

Prior to designing the DDC system, check with the Government Project Manager to see if an existing energy management network has been established on the Base. Provide DDC equipment which is compatible with existing systems to the maximum extent practicable. \1\ASHRAE's BACnet protocol is the preferred control system architecture for Navy & Marine Corp facilities and should be used where possible./1/ Where use of a specific DDC system is mandatory, a Justification and Authorization (J&A) for the utilization of proprietary DDC equipment shall be provided by the Government.

2-6.4.1 For new buildings, DDC systems shall utilize all electric or electronic actuators. On rehab projects, eliminate pneumatics whenever possible. Actuator positions or responses shall be based on position sensors or position feedback indicators and not on controller output signals.

2-6.4.2 For new installations, provide DDC equipment which is user-friendly and which maximizes compatibility with other manufacturers' equipment. \1\ Follow ASHRAE Standard 135, *BACnet, A Data Communication Protocol for Building Automation and Control Networks,* for guidance on DDC system design and compatibility/1/. Provide an operator programmable DDC system as a distributed control system. \1\Provide the minimum points as required from Table 3-1./1/

2-6.4.3 Unless combined with a larger control system, DDC controls for small HVAC systems (i.e.- DX systems of less than ~10 tons) are not cost-effective. Utilize programmable electronic thermostats for these smaller facilities

2-6.4.4 Require the DDC installer to provide training for government facility personnel on all new DDC equipment. Provide training as required by the RFP for Design/build projects, and request guidance from the base Public Works or USAF Base Civil Engineering Office where the project is located for number and type of personnel to attend.

2-6.4.5 Provide Silicon Control Rectifiers (SCRs) when precise control is required.

2-6.4.6 \1\Provide hardware equipment utilizing the latest technology which will accomplish the desired control and will meet the DoD Information Assurance Certification and Accreditation Process (DIACAP) requirements as described in DoD Instruction 8510.01, *DoD Information Assurance Certification and Accreditation Process (DIACAP)*./1/

2-6.4.7 Where direct drive fan packages are not available for rooftop fan applications, provide current sensing devices on fan motors to alarm for broken drive belts.

\1\2-6.4.8 The DDC system shall receive position signals from the fire smoke dampers./1/

2-6.5 **Multiple Chillers.**

When multiple chillers are provided, control the chillers by a single central chiller control panel provided by the chiller manufacturer. This is to ensure that the chillers are loaded and unloaded optimally for best performance, reliability, and energy efficiency. Provide connection and communication between the chiller panel and the DDC system.

2-7 **SYSTEMS TESTING & BALANCING**

2-7.1 **Balancing Valves and Cocks.**

Provide calibrated balancing valves for hydronic balance. The designer shall specify the size of the balancing valves required in each application, cognizant of the required differential pressure requirements in the pipe systems; do not assume line size valves as appropriate for the application. A balancing device is required in coil bypasses only when coil drops are in excess of 6 kPa (2 feet w.g.).

2-7.2 Flow Control Balancing Valves.

Provide flow control balancing valves in the discharges of all closed circuit pumps and at all hydronic terminals. For pipe sizes larger than 80 mm (3 inches), a flow orifice combined with a butterfly valve shall be specified. Install all flow control balancing valves in accordance with the manufacturer's recommendations regarding the minimum straight lengths of pipe up and downstream of the device. Designers shall select the proper size flow control-balancing valve for each application to ensure the devices are not oversized; valves shall be selected using the median flow rating indicated in the manufacturer's published performance data. Oversized flow control balancing valves yield inaccurate flow readings. \1\Do not use automatic flow control balancing valves./1/

2-7.3 Balancing Dampers.

\1\Except for primary VAV supply ductwork, /1/provide manual volume dampers for all main and branch ducts; these should include all supply, return, and exhaust ducts. Do not use splitter dampers or air extractors for air balancing; neither are endorsed by SMACNA for balancing applications. Provide opposed blade manual balancing damper for outside air. Indicate opposed blade manual balancing dampers for both the main supply and return duct and the main relief duct on all return air fans; dampers shall be in close proximity to the automatic return and relief dampers.

2-7.4 Duct Leakage and Testing.

\1\All new duct systems shall be constructed no less than a 1-inch pressure class and shall be leak tested./1/ Refer to Appendix D for duct pressure table \1\example and include the edited table on the mechanical construction contract drawings/1/.

2-7.5 Variable Speed Drives.

Variable speed drives on pumps or fans shall not be manually adjusted to achieve system balance. Balance systems to deliver design flows with variable speed drives operating at between 55 and 60 Hz so that maximum operational flexibility is maintained. Replace or adjust fan drive sheaves and throttle pump discharges to achieve system balance. Consider trimming pump impellers on larger systems.

2-8 OTHER HVAC SYSTEMS AND EQUIPMENT

2-8.1 Antiterrorism.

Design all inhabited buildings to meet the requirements of UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, and/or Combatant Commander Anti-terrorism/Force Protection construction Standards.

2-8.2 Conflicts.

Avoid conflicts with other disciplines and building features. Most common are: electric lights and diffusers; electric duplex outlets and fin radiation; rain leaders or soil stacks and ductwork; bond beams or joists and ducts, etc.

2-8.3 **Clearances and Equipment Service Space.**

Ensure that all equipment will fit allotted space with manufacturers' recommendations for service and maintenance space adopted. Indicate on drawings filter and tube or coil pull areas for all major equipment, including chillers, boilers, converters, etc. Verify adequate door dimensions to permit passage of equipment into mechanical spaces.

2-8.3.1 **Electrical Rooms.** No pipes (pressure or gravity) shall be installed within, or pass through, electrical or communication rooms.

2-8.4 **Seismic.**

Pipe and duct supports must comply with the requirements of SMACNA \1*Seismic Restraint Manual Guidelines for Mechanical Systems/1/*. Provide details to structural engineer for support verification and sizing.

CHAPTER 3 DESIGN ANALYSIS AND DOCUMENTATION

3-1 GENERAL

3-1.1 Field Investigation.

Conduct detailed field investigation and interview the appropriate field personnel. Do not rely solely on the as-built drawings.

3-1.2 Energy Studies.

The design A&E shall satisfy the energy conservation requirements in accordance with UFC 3-400-01, *Energy Conservation*.

3-1.3 Energy Standard.

All new facilities and major renovation projects shall conform to ASHRAE Standard 90.1, *Energy Standards for Buildings Except Low Rise Residential Buildings*. Note that compliance with this Standard imposes Architectural, Mechanical, and Electrical requirements on the design of the facility. \1\/1/

3-1.3.1 **Energy Analysis Form.** \1\HVAC system type and fuel source shall be selected based on lowest life cycle cost./1/ The number and type of alternatives to be analyzed shall be based on project information provided in the scope of work. The Energy Analysis Form (Form E-1) shall be submitted with the proposed alternatives and zones and shall be accompanied with the best available floor plan clearly depicting the zones. Upon submission to the Government by the design A&E at the project concept stage, the Government will review the recommendations and return the form to the A&E: "Approved", "Approved as Noted", or "Disapproved". Contact the Government Project Manager prior to submitting Form E-1 if you have any questions. A copy of the form is included in \1\Appendix C./1/

3-1.3.2 \1\/1/

3-1.4 Computerized Energy Analysis.

After receiving the approved forms from the Government, the A&E shall perform a computerized energy analysis and a life cycle cost analysis in accordance with the Scope of Work and UFC 3-400-01, *Energy Conservation*.

3-2 DESIGN CONDITIONS

3-2.1 Outside Design Temperatures.

Utilize the Unified Facility Criteria document, UFC 3-400-2, *Design Engineering Weather Data*, and utilize the Design Criteria Data available from the referenced Air Force Combat Climatology Center website. For Design/Build projects, the data may be defined in the RFP documents.

3-2.1.1 **Cooling Systems**:

3-2.1.1.1 **Mission-Critical Facilities, where equipment failure due to high heat would be unacceptable:** For design utilize the “0.4% Occurrence” value for outside air “Dry Bulb Temperature (T)” “Design Value (°F)” and the “Mean Coincident (Average) Values” “Wet Bulb Temperature (°F)” for the Design Cooling Day.

3-2.1.1.2 **Humid Area Facilities, Specialized De-humidification Systems, and 100% Outside Air Systems:** For design, utilize the “1% Occurrence” value of outside air “Dry Bulb Temperature (T)” “Design Value (°F)” and the “Mean Coincident (Average) Values” “Wet Bulb Temperature (°F)” for the Design Cooling Day. Also, design for Maximum Humidity conditions, using the “1.0% Occurrence” value of outside air “Humidity Ratio (HR)” “Design Value (gr/lb)” and the “Mean Coincident (Average) Values” “Dry Bulb Temperature (°F).”

3-2.1.1.3 **Other Typical Facilities and Systems:** For design, utilize the “1% Occurrence” value of outside air “Dry Bulb Temperature (T)” “Design Value (°F)” and the “Mean Coincident (Average) Values” “Wet Bulb Temperature (°F)” for the Design Cooling Day.

3-2.1.1.4 **Cooling Towers or Evaporative Cooling Equipment:** For sizing, utilize the “Median of Extreme Highs” value for outside air “Wet Bulb Temperature (T)” “Design Value (°F)” and the “Mean Coincident (Average) Values” “Dry Bulb Temperature (T)” for the Design Cooling Day.

3-2.1.2 **Heating Indoor Design Conditions.** Space Design conditions shall be 21.1 Cdb (70 Fdb) & a minimum of 30% RH, during the Design Heating Day outside air conditions. At all other than design day, occupied times, maintain the space within the “Winter” conditions shown in ASHRAE Handbook of Fundamentals – 2001, Chapter 8, Figure 5, but not more than 21.1 Cdb (70 Fdb).

3-2.1.2.1 **Heating Equipment:** For design, utilize the “99% Occurrence” value for outside air “Dry Bulb Temperature (T)” “Design Value (°F).”

Process heating conditions are determined by the respective process requirements.

> Note: Spaces requiring comfort heating shall be maintained at temperatures no higher than 21.1 Cdb (70 Fdb). During unoccupied hours, temperatures shall be set no higher than12.8 Cdb (55 Fdb).

3-2.1.2.2 **Heating Inside Design Conditions for Laboratories, Shops, Warehouses, etc:** Space Design conditions shall be 18.3 Cdb (65 Fdb) during the Design Heating Day outside air conditions for areas with moderate activity employment, 15.5 Cdb (60 Fdb) for areas with heavy activity employment, and 10 Cdb (50 Fdb) for storage areas.

3-2.1.3 **Cooling Indoor Design Conditions.** Space Design conditions shall be 24.4 Cdb (76 Fdb) & 50% RH, during the Design Cooling Day outside air conditions. At all other than design day, occupied times, maintain the space within the “Summer” conditions shown in the latest edition of ASHRAE Handbook of Fundamentals, but not less than 24.4 Cdb (76 Fdb). 100% Outside Air systems shall operate continuously in Humid Areas, to prevent mold growth.

Process cooling conditions are determined by the respective process requirements.

> Note: Spaces authorized comfort cooling shall be designed for inside temperatures no lower than 24.4 Cdb (76 Fdb). During unoccupied hours, cooling systems shall be secured where appropriate.

3-3 BASIS OF DESIGN

3-3.1 Plumbing Basis of Design.

Address the following:

3-3.1.1 **Design Criteria.** Identify the governing codes and criteria, including federal and military handbooks, utilized for the design. Include the titles and the date of the latest edition or publication. References to codes and criteria should be made in the narratives of the Basis of Design.

3-3.1.2 **Estimated Water Demand.** Estimate the water demand in L/s (gpm) based on the type and number of fixtures required for each building.

3-3.1.3 **Water Pressure.** Indicate the minimum and maximum water pressure in kPa (psi) at each building. Indicate if booster pumping will be required.

3-3.1.4 **Domestic Hot Water.** Indicate the type, size and design water temperature of the domestic water heater and the distribution system. Indicate the extent of domestic hot water recirculation within the building. If shown economically feasible by life cycle cost analysis, state whether heat recovery will be utilized. \1\Provide solar domestic water analysis per UFC 3-400-01, *Energy Conservation./1/*

3-3.1.5 **Special Mechanical Systems.** Provide a description of special mechanical systems such as compressed air, hydraulic, nitrogen, lubrication oil, etc.

3-3.1.6 **Backflow Prevention.** Identify the systems and fixtures requiring backflow preventers.

3-3.2 Mechanical Basis of Design.

Address the following:

3-3.2.1 **Design Criteria.** Identify the governing codes and criteria, including federal and military handbooks, being utilized for the design. Include the titles and the date of the latest edition or publication. References to codes and criteria should be made in the narratives of the “Basis of Design”.

3-3.2.2 **Design Conditions.** Provide a tabulation of the design indoor and outdoor heating and cooling conditions for all occupied and unoccupied areas.

3-3.2.3 **Base Utilities.** Describe the source of thermal energy that will be used (i.e. extension of central high pressure steam, hot water, natural gas, or stand alone heat source with the type of fuel utilized). Where more than one source of thermal energy is considered economically feasible, or where a facility is deemed appropriate for study as defined under the heading entitled "Energy Computations", include a computerized Life Cycle Cost Analysis to justify the selection. Metric and English conversion factors are shown in Table D-1 in Appendix D.

3-3.2.4 **Heating System.** Provide a description of the heating system proposed, including an explanation of why this system is preferred over others. Indicate locations of major components of the system. Resistance electricity and L.P. gas are not allowed for space comfort heating, except with approval of the mechanical branch head.

3-3.2.5 **Ventilation System.** State whether a gravity or mechanical system is to be used and provide a brief description of the ventilation system proposed. Indicate the outside air ventilation rates in cfm/person (L/s/person) for various room types. The prescribed rates must be in compliance with \1\ASHRAE Standard 62.1 *Ventilation for Acceptable Indoor Air Quality/1/*. Describe the operation of the ventilation system in summer and winter modes. Indicate the number of outside air changes per hour in various areas, the type of infiltration, and whether OSHA requirements are applicable.

3-3.2.6 **Cooling System.** Provide a description of the cooling system proposed including an explanation of why this system is preferred over others. Indicate locations of major components of the system. Identify special humidification or dehumidification requirements. Indicate ASHRAE Standard filter efficiencies and any other special filtration requirements.

3-3.2.7 **HVAC Control System.** Briefly describe the HVAC control system type and its functions. If applicable, indicate a requirement to tie into an existing Base-wide \1\UMCS/1/.

3-3.2.8 **Sustainable Design.** Briefly describe all energy and water conservation features, systems, and components used in the project and the expected energy savings \1\in accordance with EPACT05 calculation requirements/1/. Describe all features being utilized for lead credits and include the completed LEED forms.

3-3.2.9 **Energy Conservation.** Provide mechanical system based on lowest life cycle cost. Provide completed compliance forms provided in ASHRAE 90.1 User's Manual and any additional documentation to support compliance with this Standard, including a narrative describing the method of compliance, descriptions of building systems and components to be incorporated, and computer analysis discussion, input and output. \1\/1/

3-4 CALCULATIONS

3-4.1 Plumbing Calculations.

Plumbing system design shall comply with the requirements of UFC 3-420-01, *Plumbing Systems*.

The following calculations are required:

3-4.1.1 **Domestic Hot Water Heating.** Calculate the hot water storage and demand requirements of the facility. Indicate the basis for the calculations including the incoming and storage water temperatures, the facility type, fixture types, fixture quantities, and the demand and storage factors.

3-4.1.2 **Domestic Water Pressure Calculations.** Determine the sufficiency of the water pressure available at the building to meet the required minimum fixture outlet pressure. Provide detailed pressure loss calculations including losses attributed to meters, fittings, pipe, backflow preventers, and pipe risers.

3-4.1.3 **Domestic Hot Water Recirculation.** Reference the plumbing code by which the domestic hot water recirculation rate is calculated. Calculate the recirculation rate and the recirculation pump head.

\1\3-4.1.4 **Solar Domestic Hot Water Calculations**. Provide solar domestic hot water calculations including system sizing & capacity./1/

3-4.2 Mechanical Calculations.

The following calculations are required:

3-4.2.1 **"U" Factor Calculations.** \1\Follow the building envelope thermal requirements of UFC 3-101-01, *Architecture,* Chapter 3./1/ Calculate "U" factors \1\including thermal bridging/1/ for all composite wall and roof systems using the latest edition of ASHRAE Fundamentals. Include cross sections drawings of all wall and roof systems to supplement the calculations.

3-4.2.2 **Building Exhaust Calculations.** Calculate exhaust requirements for removal of heat, fumes, dust, and vapors in various spaces in accordance with ASHRAE. Provide a building exhaust summary.

3-4.2.3 **Outside Air Requirements/Calculations.** Calculate the outside air ventilation requirements as prescribed by \1\ASHRAE Standard 62.1 *Ventilation for Acceptable Indoor Air Quality*/1/. Calculations must consider the factors of "Multiple Spaces", "Ventilation Effectiveness" and "Intermittent or Variable Occupancy" as specified in \1\ASHRAE Standard 62.1./1/ Provide a summary showing compliance with the ventilation requirements.

3-4.2.4 **Building Air Balance Calculations.** Provide air balance calculations addressing the relationship between supply, return, outside air, and exhaust air quantities and indicating pressurization. Special requirements for space pressurization shall be reflected and referenced in the air balance calculations.

3-4.2.5 **Heating and Cooling Load Calculations.** Use of professionally recognized, nationally used computerized load calculating program is required. Load calculations are required for each room or zone by the ASHRAE method indicated in the latest edition of the Fundamentals Handbook. Copies of input and output data are required. Psychrometric calculations shall be illustrated on psychrometric charts and submitted with the 100% submittal. Computer disks may also be requested (see 100% submittal requirements).

3-4.2.6 **Duct Pressure Drop Calculations.** Provide pressure drop calculations for all supply, return, outside and exhaust air systems \1\in accordance with the ASHRAE Fundamentals Handbook/1/. All Variable Air Volume (VAV) supply duct systems shall be sized by the static regain method. Equal friction method shall be used for VAV return ducts. The static regain, equal velocity or equal friction methods may be performed on non-VAV supply duct systems.

3-4.2.7 **Hydronic System Pressure Drop Calculations.** Provide pressure drop calculations for all supply and return piping systems.

3-4.2.8 **Pipe Expansion Calculations.** Provide pipe stress calculations for all low-pressure 103 kPa (15 psi) steam, condensate and hot water piping systems where pipe diameters exceed 100 mm (4 inches) and/or the length exceeds 30 m (100 linear feet) without a directional change. Provide pipe stress calculations for all medium and high-pressure steam and high temperature hot water systems.

3-4.2.9 **Equipment Sizing Calculations.** Provide equipment sizing calculations and \1\manufacturer's performance data of equipment selected for basis of design. If applicable, provide psychrometric calculations and charts to justify the selection of equipment, including the following/1/:

a. Terminal equipment including VAV boxes, fan coil units, etc.
b. Pumps. \1\/1/
c. Fans.
d. Air Handling Units.
e. Chillers.
f. Boilers.
g. Closed Circuit Coolers and Cooling Towers.

3-4.2.10 **Heat Gain Calculations.** Perform heat gain calculations for duct systems using 90% insulation efficiency. \1\ Calculate heat gain from chilled water pumps and include in the sizing of the chilled water system. /1/

3-4.2.11 **Duct Leakage Calculations.** Provide for high pressure systems 746 Pascals or greater (3 inches of water column or greater). Calculate the expectant duct leakage based on the designer's requirements for the duct, seal, and leakage classes for each duct system using the latest edition of the SMACNA *HVAC Air Duct Leakage Test Manual*.

3-5 DRAWINGS

Drawings shall be sufficiently complete to indicate all aspects of installation. Where alternate methods or systems are intended, drawings must detail both alternatives. Judgement should be exercised to avoid overly congested drawings.

3-5.1 Drawing units

Unless otherwise authorized, the SI system of measurement shall be utilized on the drawings in accordance with UFC 1-300-09N, *Design Procedures*. Metric and English pipe sizes are listed in Table D-2 in Appendix D.

3-5.2 Seismic.

Show all pertinent seismic detailing on the contract drawings.

3-5.3 Plumbing Drawings

3-5.3.1 **Demolition.** "Demolition" plans should be separate and distinct from "new work" plans.

3-5.3.2 **Orientation.** Provide north arrows an all building and site plans. The orientation of plumbing drawings shall be arranged with the north arrow toward the top of the plotted sheets, unless overriding circumstances dictate otherwise. The orientation of all partial building or site plans shall be identical to that of the larger plan from which it is derived or referenced. Consistency in drawing orientation shall be maintained with all disciplines.

3-5.3.3 **Legend.** Provide legends to clarify all symbols and abbreviations used on the plumbing drawings.

3-5.3.4 **Enlarged Plans.** Enlarged plans shall be drawn at no less than 1:50 (¼" = 1'-0").

3-5.3.5 **Riser Diagrams.** Provide separate waste and water riser diagrams for all fixture groupings. All riser diagrams shall be drawn 3-dimensional (flat, 2-dimensional risers are unacceptable) and shall account for all pipe directional changes indicated on the floor plans.

3-5.3.6 **Plumbing Fixture Schedule.** Provide a fixture schedule utilizing fixture designations coordinated with the contract specifications.

3-5.4 Mechanical Drawings

3-5.4.1 **Demolition.** "Demolition" plans should be separate and distinct from "new work" plans.

3-5.4.2 **Orientation.** Provide north arrows an all building and site plans. The orientation of mechanical drawings shall be arranged with the north arrow toward the top of the plotted sheets, unless overriding circumstances dictate otherwise. The orientation of all partial building or site plans shall be identical to that of the larger plan from which it is derived or referenced. Consistency in drawing orientation shall be maintained with all disciplines.

3-5.4.3 **Legend.** Provide legends to clarify all symbols and abbreviations used on the mechanical drawings.

3-5.4.4 **Design Conditions.** Provide a schedule indicating indoor and outdoor design temperatures for each room type.

3-5.4.5 **Floor Plans.** Exercise judgment to avoid overly congested drawings. When drawing congestion is likely, ductwork and piping should not be shown on the same plan. \1\Single line ductwork layouts are not allowed on final drawings. A two line ductwork layout to scale will be provided./1/

3-5.4.6 **Sections and Elevations.** Provide as required to supplement plan views.

3-5.4.7 **Enlarged Plans.** Mechanical rooms should be drawn at no less than 1:50 (¼" = 1'-0"). Congested mechanical rooms shall be drawn at no less than 1:20 (½" = 1'-0"). Mechanical room plans should be supplemented by at least one section; at least two sections for more complex, congested applications.

3-5.4.8 **Schematic Diagrams.** Provide a 3-dimensional isometric diagram representing the mechanical room piping or a 2-dimensional diagram indicating the entire system.

3-5.4.9 **Kitchen Hood Diagram.** Provide a detailed air balance diagram on the drawings for every kitchen/dining facility design to show compliance with the ventilation requirements. Indicate required capture velocities and capture distances for all hoods on the drawings. Provide notes and contractor instructions on plans indicating that fan airflows shown for hoods are approximate and requiring the contractor to balance the system to achieve the capture velocities indicated. The scheduled fan and motor size shall allow for adjustment of the airflow.

3-5.4.10 **Details.** Details shall be edited to reflect the configurations and construction materials shown on the plans.

3-5.4.11 **Flow and Slope Arrows.** Indicate the flow direction of pipe on the drawings. Show slope direction and rate of slope on all piping systems.

3-5.4.12 **Duct Construction Classifications.** \1\Indicate duct static pressure, and include Table D-4, the "Ductwork Construction and Leakage Table" on the drawings to indicate required seal and leakage classifications in accordance with SMACNA-*HVAC Air Duct Leakage Test Manual*./1/

3-5.4.13 **Guides for Piping.** Show pipe guide locations on all aboveground anchored piping.

3-5.4.14 **Pipe Anchors.** Show anchor locations on plans. Provide anchor detail(s).

3-5.4.15 \1**Acoustic Duct.** Indicate double-wall duct where required on the drawings. Drawings shall indicate the inside clear dimensions of ducts./1/

3-5.4.16 **Door Louvers.** Show location or coordinate with architectural drawings.

3-5.4.17 **Roof Fans.** Details of roof exhaust fans shall include a requirement for airtight seals between the fan frame and the wood nailer of the roof curb. The details shall require the duct of ducted exhaust fans to extend up through the fan curb to a flanged and sealed termination at the top of the curb.

3-5.4.18 **Equipment Supports.** Show hanger rods and structural supports for all ceiling or roof-mounted air handling units, heating/ventilating units, fan coil units, exhaust or supply fans, expansion tanks, etc in drawing details.

3-5.4.19 **Pressure Gauges.** Indicate pressure gauge ranges; system operating pressures should be midrange on the graduated scale.

3-5.4.20 **Cold Water Make-up.** Detail all accessories, to include pressure reducing valves (PRV), relief valves, and backflow preventers. Show pressure reducing and relief valve pressure settings.

3-5.4.21 **Air Vents.** Show location of automatic and manual air vents required in piping systems.

3-5.4.22 **Drain Lines.** Show drain lines from air handling units, fan coil units, etc.

3-5.4.23 **Fouling Factors.** Indicate fouling factors for all water-to-air and water-to-water heat exchangers (i.e. coils, converters, chillers, etc). Indicate in the appropriate equipment schedule. Fouling factors shall be accompanied with their appropriate English or SI units.

3-5.4.24 **Equipment Schedules.** The HVAC equipment actually installed on a project may be different from that used as your basis of design. Therefore, mechanical equipment schedules shall reflect actual required equipment capacities as calculated, not capacities provided by manufacturers' catalog data. This helps ensure that the installed equipment is optimally sized for the application.

3-5.4.25 **Motor Starters.** Indicate motor starter NEMA sizes in the mechanical equipment schedules.

3-5.4.26 **Control Valves.** Indicate flow rates, minimum Cv or maximum pressure drop, nominal valve size, service (i.e. steam, hot water, etc), configuration (i.e. 2-way or 3-way), and action (i.e. modulating or 2-position). Use a “Control Valve Schedule”.

3-5.4.27 **Metric Valve Coefficient.** The metric version of the valve coefficient, Kv, is calculated in cubic meters per second at 1 kPa pressure drop. Do not use Cv, the English version, on a metric project.

3-5.4.28 **Balance Valves.** Contract drawings shall specify the valve size and flow for each application. When an existing system is modified, provide all information required for re-balancing in the construction documents. Detail installation of all flow control balancing valves.

3-5.4.29 **Balance Dampers.** All dampers and their intended locations shall be clearly delineated on the floor plans.

3-5.4.30 **Control Diagrams.** Provide for all HVAC systems. Show controller functions, such as normally open (NO), normally closed (NC), common (C), etc. Indicate all set points.

3-5.4.31 **Thermostats.** Show thermostat locations on the plans. Identify heating, cooling, heating/cooling and ventilation thermostats. Indicate thermometer temperature ranges; system operating temperature should be midrange on the graduated scale.

3-5.4.32 **Humidistats.** Show locations on drawings, when required.

3-5.4.33 **Controls.** Show system control schematics and a detailed written sequence of controls on the drawings for each mechanical system. Describe all controlled equipment operating modes, sequence of events, set points, and alarms. For Direct Digital Control (DDC) systems, include an input/output points list and a system architecture schematic. Table 3-1 indicates a minimum points list per system (to be used as applicable).

3-5.4.34 **Ductwork Testing.** Indicate those HVAC duct systems to be leak tested on the contract drawings. Specify the test type and test pressure for each duct system (supply air, return air, exhaust air, and outside air ductwork) subject to testing. See "Duct Construction Classifications".

3-5.4.35 **Site Work.** Show the type and routing of the heat source conveyance system on the drawings. Exterior above and below grade steam and condensate distribution and below grade chilled and hot water distribution plans shall be accompanied by profile drawings. Profile drawings shall clearly depict all other utilities in the proximity of the new work.

Table 3-1. DDC Minimum Points List

Hot Water Heating System	**VAV System**
a) Hot water pump status b) Hot water supply temperature c) Hot water return temperature d) Hot water flow rate e) Hot water mixing valve position f) Differential pressure across pump g) Boiler status h) Alarms i) Heat exchanger inlet temperatures j) Heat exchanger leaving temperatures k) Building steam meter l) Variable speed pump drive frequency	a) VAV box inlet velocity pressure b) Airflow rate of each VAV box c) Fan control start/stop d) Air valve actuator e) VAV box damper position f) Discharge air temperature at each VAV box g) VAV box hot water valve position h) Electric reheat (on/off and number of stages) i) Space temperature for each zone with set point adjustment \1\/1/
Chilled Water System	**Air Distribution System**
a) Chiller enable/disable b) Chiller status c) Entering and leaving water temperatures at each chiller d) Chilled water flow rates for each chiller e) Secondary loop chilled water flow rate f) Chilled water supply and return temperatures for the central plant g) Water temperature in the common piping of the primary/secondary loop h) Chilled water system differential pressure at central chilled water plant i) Chilled water system differential pressured used for control of secondary pumps j) Primary chilled water pump start/stop k) Primary chilled water pump status l) Outside air temperature m) Outside air relative humidity\1\/1/ n) Cooling tower fan status (high-low-off) o) Cooling tower fans - Adjustable frequency drive functions and alarms p) Condenser water supply and return temperature q) Cooling tower bypass valve position r) Variable speed pump drive frequency	a) Supply air temperature b) Supply air static pressure c) Supply airflow rate d) Outside air temperature e) Return air temperature f) Mixed air temperature g) Discharge temperature from each heating or cooling coil h) Filter status i) Supply/return damper positions j) Outside air damper positions k) Chilled water valve positions l) Hot water valve positions m) Electric heater status (on/off and number of stages energized or % power) n) Freezestat o) Smoke detector p) Supply fan start/stop q) Supply fan speed control r) Supply fan run status s) Supply fan fault status t) Exhaust fan run status u) Outside air fan run status v) Heat recovery wheel rotation status \1\w) Fire damper status/1/
\1\General Building Systems/1/	
\1\a) Building electrical meter b) Building water meter c) Building natural gas meter d) Building steam meter/1/	

APPENDIX A - REFERENCES

\1\Unless indicated below,/1/ utilize the latest Code or standard edition applicable, including any amendments, at the time of award of contract. Where there is a conflict between Naval Criteria and National Codes follow Naval Criteria. Refer to CCB for other applicable criteria. Comply with the required and advisory portions. All work shall comply with \1\/1/ all applicable criteria, standards, and codes including, but not limited to, the following:

GOVERNMENT PUBLICATIONS:

Federal Energy Management Program (FEMP)

Energy Star Program

Military Handbooks/Standards

\1\ DoD Instruction 8510.01, *DoD Information Assurance Certification and Accreditation Process (DIACAP) /1/*

AF ETL 04-3, *Design Criteria for Prevention of Mold in Air Force Facilities*

\1\Interim Technical Guidance (ITG) FY05-02, *NAVFAC Humid Area HVAC Design Criteria*/1/

Unified Facilities Criteria (UFC)

UFC 1-200-01, *General Building Requirements*

\1\UFC 1-300-09N, *Design Procedures*/1/

\1\UFC 3-101-01, *Architecture* /1/

\1\UFC 3-310-04, *Seismic Design for Buildings /1/*

UFC 3-400-01, *Energy Conservation*\1\/1/

UFC 3-410-04N, *Industrial Ventilation Systems*

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

UFC 3-420-01, *Plumbing Systems*

UFC 3-430-08N, *Central Heating Plants*

UFC 3-430-09, *Exterior Mechanical Utility Distribution*

UFC 3-460-01, *Design: Petroleum Fuel Facilities*

UFC 3-580-10, *Navy and Marine Corps Intranet (NMCI) Standard Construction Practices*

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

UFC 3-600-10N, *Fire Protection Engineering*

\1\UFC 3-800-10N, *Environmental Engineering for Facility Construction*/1/

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

\1\UFC 4-030 01, *Sustainable Development/1/*

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

UFC 4-721-10, *Navy and Marine Corps Bachelor Housing*

\1\UFC 4-722-01, *Dining Facilities*/1/

Standard Government publications are available at www.hnd.usace.army.mil/techinfo.

\1\UFCs and ITG's are available at http://www.wbdg.org /1/

NON-GOVERNMENT PUBLICATIONS:

American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)

\1\ASHRAE Standard 90.1-2007, *Energy Standards for Buildings Except Low Rise Residential Buildings/1/*

\1\ASHRAE Standard 15-2010, *Safety Standard for Refrigeration Systems/1/*

\1\ASHRAE Standard 62.1-2010, *Ventilation for Acceptable Indoor Air Quality/1/*

\1\ASHRAE Standard 135-2010, *BACnet, A Data Communication Protocol for Building Automation and Control Networks/1/*

ASHRAE Handbooks

International Ground Source Heat Pump Association (IGSHPA)

Ground Coupled Heat Pump System Design Guide

Building Codes

The International Building Code (IBC)

The International Mechanical Code (IMC)

The International Plumbing Code (IPC)

National Fire Protection Association (NFPA)

NFPA 30, *Flammable and Combustible Liquids Code*

NFPA 54, *National Fuel Gas Code*

NFPA 58, *Liquefied Petroleum Gas Code*

NFPA 70, *National Electrical Code*

NFPA 90A, *Air Conditioning and Ventilating Systems*

NFPA 90B, *Warm Air Heating and Air Conditioning Systems*

Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)

HVAC Air Duct Construction Standards

HVAC Air Duct Leakage Test Manual

Seismic Restraint Manual \1\Guidelines for Mechanical Systems/1/

U.S Green Building Council

LEED Rating System

APPENDIX B - BEST PRACTICES

B-1 HVAC SYSTEMS

B-1.1 Consider heat recovery for all air systems or buildings providing 2500 cubic feet per minute or greater of outdoor ventilation air.

B-1.2 Consider variable speed pumping on all distribution systems with pumps two horsepower or greater.

B-1.3 Maximize distribution air and water temperature differences to reduce flow rates.

B-1.4 Consider radiant heating systems for hangars and other large, open areas.

B-2 CHILLERS

B-2.1 Specify efficiency based on IPLV part load efficiency unless chiller is expected to mostly fully loaded.

B-3 COOLING TOWERS

B-3.1 Use induced draft fans instead of forced draft fans.

B-3.2 Use variable speed fan motors for capacity control for fans of two horsepower and over.

B-3.3 Design tower based on ASHRAE 0.4% design wet bulb temperature.

APPENDIX C - ENERGY FORM

1-1 \1\ENERGY FORM. /1/

Contact the Mechanical Engineering Branch prior to submitting any forms, for applicability or if you have any questions. The Energy Analysis Form (Form E-1) \1\/1/shall be submitted to the Mechanical Engineering Branch for review and recommendations.

Energy Analysis Form (E-1)

Constr Contr No.: ____________________________
Project No.: P-____________ FY: ___________
Project Title: ________________________________
Location: ___________________________________
A&E Firm:

Building Information

Estimated Cooling: ___________ **(tons) (kW)**
Number of Zones: ___________
Building Floor Area: ___________ (sf) (sm)
Zone Descriptions: **(attach annotated floor plan)**

____
____
____
____
____
____
____
____
____
____
____

Energy Analysis Program (check one):

☐ **BLAST**
☐ Carrier **EC** 20-**II HAP**
☐ **DOE** 2.1
☐ Trane Trace-Ultra
\1\ ☐ eQuest /1/
☐ Other. Indicate: ____________________
(provide documentation)

Study Alternatives

Alternatives (Describe heating, ventilation and cooling systems; list primary & terminal equipment, energy source (steam, electric, mech etc), & air or water cooled heat rejection)	FOR **GOVERNMENT** USE ONLY			
	*A	*AN	*D	**Remarks**
#1				
#2				
#3				
#4				

*** "A" – Approved; "AN" – Approved as Noted; "D" – Disapproved & Resubmit**

This completed and signed form must be included in the "Basis of Design."

\1**NAVFAC**/1/ **Approved: Name:** ________________________________ **Date:** ___________

APPENDIX D - STANDARD CONVERSIONS AND TABLES

Table D-1. Fuel Conversion Factors

Type of Fuel	Conversion Factors (See note (a))	Notes
Anthracite Coal	28.4 Million Btu/Short Ton	
	29.9 kJ/kg	
Bituminous Coal	24.6 Million Btu/Short Ton	
	25.9 kJ/kg	
Electricity	3413 Btu/KWH	See note (b)
	12.3 MJ	
No. 2 Distillate Fuel Oil	138,700 Btu/Gallon	
	38.7 MJ/L	
Residual Fuel Oil	149,700 Btu/Gallon	
	41.8 MJ/L	
Kerosene	135,000 Btu/Gallon	
	37.7 MJ/L	
LP Gas	95,500 Btu/Gallon	
	26.6 MJ/L	
Natural Gas	1,031 Btu/Cubic Foot	
	38.5 MJ/L	
Purchased or Steam from Central Plant	1,000 Btu/Pound	See note (c)
	2.3 MJ/kg	

Notes:

(a) At specific installations where the energy source Btu content is known to vary consistently by 10% or more from the values given below, the local value may be used provided there is adequate data on file for two years or more to justify the revision and that this value is expected to hold true for at least five years following building occupancy.

(b) When 10% of more of a building's annual heating consumption will be derived from electric resistance heating, the electric resistance portion shall be multiplied by a factor of 2.2 to reflect additional conversion losses.

(c) High temperature, medium temperature, or chilled water from a central plant shall use the heat value of fluid based on the actual temperature and pressure delivered to the 1.5 m (5 ft) line.

Table D-2. Metric Pipe Size Equivalence

NPS (Inches)	DN (mm)	NPS (Inches)	DN (mm)
1/8	6	2-1/2	65
3/16	7	3	80
1/4	8	3-1/2	90
3/8	10	4	100
1/2	15	4-1/2	115
5/8	18	5	125
3/4	20	6	150
1	25	8	200
1-1/4	32	10	250
1-1/2	40	12	300
2	50		

Notes:
1. NPS is the inch-pound designation for “nominal pipe size”.
2. DN is the metric designation for “diameter nominal”.
3. For pipe sizes over 12 inches, use the conversion factor of 25 mm per inch.

Table D-3. Metric Ductwork Dimensions

Inches	mm
3	80
4	100
5	130
6	150
7	180
8	200
10	250
12	300

Notes:
1. For dimensions over 12 inches, increase mm size in increments of 50.

Table D-4. \1\Ductwork Construction and Leakage Testing Table Example/1/

System	Duct Pressure Class Inches of Water Column				Supply Round/Oval		Supply Rectangular		Return/ Outside Air		Duct Test Pressure: Inches of Water Column	Notes
	Supply Duct	Return Duct	Exhaust Duct	Outside Air Duct	Duct Seal Class	Duct Leak Class	Duct Seal Class	Duct Leak Class	Duct Seal Class	Duct Leak Class		
Packaged Rooftop - VAV	4	-	-	-	A	3	A	6	-	-	4.0	1
	-	-2	-	-	-	-	-	-	A	24	2.0	1
Packaged Rooftop -CV	2	-	-	-	-	-	A	12	-	-	2.0	1
	-	-1	-	-	-	-	-	-	A	24	1.0	1
Air Handling Unit with Economizer -Constant Volume	2	-	-	-	A	6	A	12	-	-	2.0	1
	-	-1	-	-	-	-	-	-	A	24	1.0	1
	-	-	-.5	-	-	-	A	24	-	-	0.5	1
	-	-	-	-1	-	-	-	-	A	24	1.0	1
Series VAV Terminal Boxes	2	-	-	-	-	-	A	12	-	-	2.0	1
	-	-.5	-	-	-	-	-	-	A	24	0.5	1
Exhaust Duct	-		-1	-	-	-	A	24	-	-	1.0	1

Notes:

1. Test in accordance with \1\UFGS 23 05 93, *Testing, Adjusting, and Balancing for HVAC* and the procedures in SMACNA HVAC Air Duct Leakage Test Manual including the Navy requirements in excess of SMACNA listed below. /1/
2. \1\Each piece of air moving equipment on the project must be shown in the schedule and the required pressure class, duct seal class, duct leak class and test pressure must be indicated./1/

\1\Navy requirements in excess of SMACNA:

1. For duct pressure classes less than 2”, the allowable duct leakage class is 12 for round/oval ductwork and 24 for rectangular ductwork.
2. For duct pressure classes from 2”to less than 4”, the allowable duct leakage class is 6 for round/oval ductwork and 12 for rectangular ductwork.
3. For duct pressure classes of 4” or greater, follow SMACNA requirements./1/

APPENDIX E - ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Government Industrial Hygienists
AFMS	Airflow Measuring Stations
AFOSH	Air Force Occupational Safety and Health
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
AT	Anti-Terrorism
BH	Bachelor Housing
C	Celsius
CAV	Constant Air Volume
Cdb	Celsius Dry Bulb
CFM	Cubic Feet per Minute
CO	Carbon Monoxide
DDC	Direct Digital Controls
DoD	Department of Defense \1\/1/
EPACT05	Energy Policy Act of 2005
F	Fahrenheit
Fdb	Fahrenheit Dry Bulb
FEMP	Federal Energy Management Program
GCHP	Ground Coupled Heat Pump
GHz	Gigahertz
GPM	Gallon Per Minute
HVAC	Heating, Ventilating and Air Conditioning
Hz	Hertz
IBC	International Building Code
IESNA	Illuminating Engineering Society of North America
IGSHPA	International Ground Source Heat Pump Association
IMC	International Mechanical Code
IPC	International Plumbing Code
ITG	Interim Technical Guide
J&A	Justification & Authorization
kPA	Kilopascals
LEED	Leadership in Energy and Environmental Design
m	Meters
mm	Millimeters
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
ODS	Ozone Depleting Substances
\1\ODP	Ozone Depletion Potential/1/
OSHA	Occupational Safety and Health Administration
Pa	Pascal
PI	Pressure Independent
PRV	Pressure Reducing Valve
psi	Pounds per Square Inch
RFP	Request for Proposal
RH	Relative Humidity

SCR	Silicon Control Rectifier
SFPVAV	Series Fan-powered Variable Air Volume
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
T	Temperature
UFC	Unified Facilities Criteria
UL	Underwriters Laboratories
\1\UMCS	Utility Management &Control System/1/
VAV	Variable Air Volume
w.g.	Water Gauge