CHAPTER 7

HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS

7-1. General heating, ventilating, and air-conditioning (HVAC) design

The DOD owns and operates many C4ISR facilities across the nation and abroad, ranging from small computer rooms to large radar facilities. C4ISR facilities often house computer and communications equipment, radar systems, printers, disk and tape drive, monitors, and system consoles – all of which generate substantial amounts of heat. To optimize performance and ensure continued operation, the environment containing the electronic equipment must be maintained within stringent temperature and humidity levels. In addition, the comfort needs of personnel required to operate the equipment must be met and the airborne particulate matter effectively filtered from entering the C4ISR room airstream. The electronic equipment and personnel must also be protected from electromagnetic pulse (EMP) phenomena, biological contamination, and radiation. In the event of a power failure, a backup system must be available to provide chilled water and cooling air to the water- and air-cooled electronic equipment, respectively, for at least 15 minutes.

a. The information present here is not intended to replace the design analysis. Cooling systems must be designed on a case-by-case basis, with consideration given to such factors as cost, location, and mission criticality of the C4ISR facility.

b. With the rapid advancements in state-of-the-art electronics, existing equipment within C4ISR facilities is constantly being replaced by new, efficient, and more powerful models. As a result, electronic equipment with these facilities is continually relocated to enhance the performance of particular facility functions. In addition to equipment relocation, the volume of equipment inside a C4ISR building often increases over time. The cooling systems used to maintain environmental conditions with individual C4ISR rooms must be designed to adapt to these changing circumstances, while still maintaining adequate filtration, EMP protection, and backup. Conventional, commercially available HVAC equipment is generally adaptable to use in C4ISR facilities whether aboveground or underground.

c. General guidelines for design of HVAC systems will be in accordance with TM 5-810-1 Mechanical Design Heating, Ventilating, and Air Conditioning. Criteria for the design of HVAC systems in humid areas are also addressed in TM 5-810-1.

d. Policies, criteria, procedures, and responsibilities for operation, maintenance, repair, and construction of facilities and systems for the efficient and economical management of Heating, Ventilating, Air Conditioning & Refrigeration (HVAC&R) utility services shall be in accordance with Army Regulation (AR) 420-49, Utility Services.

e. All mechanical systems shall have the capability of being remotely controlled from the control room. Upon a loss of normal electrical power, HVAC systems serving mission critical areas or systems shall be powered from the emergency generators. HVAC equipment and systems whose loss of power would impact the facility mission (i.e., 15-minute chilled water backup pump, computer room air-conditioning units, controls, and Chemical, Biological, and Radiological [CBR] blowers) will be operated from the UPS system until the facility generators can restore power.

f. The design conditions for the indoor and/or outdoor HVAC systems will be in accordance with the design guidance in TM 5-810-1. Design conditions for electronic equipment areas will deviate from those required for comfort conditioning only to the extent required to support the equipment to be housed within the area.

7-2. Heating, ventilating, and air conditioning (HVAC) equipment reliability and survivability

HVAC equipment installed in C4ISR facilities shall meet the following reliability and survivability goals.

a. Reliability. In mission critical facility applications, mechanical components, such as computer room type air-conditioning units, chillers, and mechanical pumps, shall have N + 2 redundancy, where N is the minimum number of units required and 2 is the required number of redundant units. If the mission is less critical, one extra unit (N + 1) may be adequate. Three factors dictate the level of redundancy required: (1) critical nature of the mission, (2) equipment reliability, and (3) equipment cost. The authority having jurisdiction and the design engineer(s) shall assess these factors when determining the level of redundancy required for a specific C4ISR facility. Redundant units will be designed to automatically start and maintain the load should the operating unit fail. Due to the high degree of reliability required for computer cooling systems, redundant components on the control system(s) may be justified.

b. Survivability. HVAC equipment installed in C4ISR facilities will be of such design or otherwise protected to withstand seismic effects as well as shock (ground motion) and overpressure effects of weapons. A detailed dynamic analysis will be made of the supporting structure(s) of the HVAC equipment to evaluate the magnitude of motion and acceleration established at the mounting points for each piece of HVAC equipment. Where accelerations exceed the allowable limit of equipment available, the equipment will be mounted on shock isolation platforms. The design will include, where feasible, certain features which will enhance the survivability of the HVAC equipment. For example, double inlet fans and double suction pumps are more likely to withstand shock forces generated by ground motion with the fan wheel and impeller supported on both sides. Conversely, single inlet fans and pumps with overhung wheels and impellers should not be used in C4ISR installations unless they are mounted on shock isolated platforms.

7-3. Mission critical areas and control room (CR)

Mission critical areas such as command centers, radar installations, and similar areas will generally contain computers and ancillary equipment which are sensitive to extremes of temperature, humidity, and the presence of duct. Computer and electronic equipment will deviate from indoor design conditions for comfort cooling, including temperature, humidity, and level of filtration, to the extent required to support the computers and equipment housed within the area. The HVAC system supporting the mission critical areas and systems shall be dedicated to those areas and systems and shall not be shared with other non-mission areas.

a. Air handling equipment. Computer room air-conditioning units located within the mission critical areas of the C4ISR facility are typically chilled water type units served by a liquid chilling system. Where practical, divide the area's cooling load between two or more smaller units to satisfy the required cooling capacity. This will generally reduce the energy consumption at partial cooling loads and will also increase overall system reliability. The use of multiple computer room type air-conditioning units (i.e., N + 2 rule) provides redundancy required for these facilities.

b. Air distribution systems. A variety of methods can be used to distribute conditioned air in electronic equipment areas.

(1) Most electronic equipment rooms use a raised floor as the underfloor plenum supply air system. Perforated floor panels are used with the underfloor plenum for providing good flexibility in accommodating potential relocation of equipment. The air distribution pattern can be modified by simply exchanging standard floor panels with perforated floor panels to satisfy the changing locations of concentrated cooling loads. The number and size of supply air outlets in the raised floor should be based on delivering 80 percent of the total supply air. The remaining 20 percent of the supply air should be routed to the room via cable cutouts in the raised floor. Raised floors using underfloor plenum and perforated floor panels can also handle load expansion by accommodating additional air handling units. Specify supply outlets suitable for installation in floors on which it is anticipated that equipment will be moved.

(2) Other types of supply air distribution systems consist of ceiling plenum supply and overhead ducted supply systems. These supply air systems are generally not as flexible as the underfloor plenum supply system and are less desirable.

(3) When the computer room air-conditioning units are located in the electronic equipment room, return air can be drawn directly back into the computer room air-conditioning units, eliminating the need for return air plenums or ducts. Such a configuration is called a free return system. With a free return system, the computer room air-conditioning units should be located near the concentrated cooling loads. Outside air is not introduced and mixed with return air in a free return configuration. Outside air must be introduced into the C4SIR room by a separate system (such as a central station air handler or make-up air system) to satisfy minimum ventilation requirements and maintain positive pressure within the electronic equipment room. The free air return system is the most flexible and the least expensive of the return air systems.

(4) Other types of return air systems consist of ceiling plenum return and overhead ducted return systems. These return air systems are generally not as flexible as the free air return system and are less desirable. Where ceiling plenum return or overhead ducted return systems are used, locate ceiling return registers near heat producing equipment.

7-4. Chillers

The number and size of chillers serving non-mission critical systems and areas will be optimized by life cycle cost analysis. Criteria used in the design and procurement of any type of liquid chiller will maximize, to the extent practical, the optimum energy efficiency of the equipment. Where there is a combination of normal summer air-conditioning loads and year round air-conditioning loads, optimize the system zones and size the system components to support the entire facility load during warm weather and a portion of the equipment may be essentially fully loaded during winter operations. Where multiple chillers are specified, provide a chilled water pump and a condenser pump for each chiller. Pumps will be piped and valved in such a manner as to be interchangeable for use with any chiller for maintenance and repair.

a. Frequently, at least three chillers, each capable of handling more than the total cooling load, are installed in a C4ISR facility. This is referred to as the “N + 2 rule.” Normally, two of the chillers are run at partial load to satisfy the cooling requirements. The third chiller is used as a backup. If one of the two operating chillers fails, the other can handle the whole load, while the third chiller still provides the required redundancy. Since centrifugal chillers are typically used in the larger capacities (over 200 tons), they are usually water cooled by a flooded, shell-and-tube condenser connected to an evaporative cooling tower. Typically below 200 tons, reciprocating chillers or rotary screw chillers would be used.

b. HVAC systems serving mission critical areas whose chilled water is supplied from central refrigeration plants shall be provided with an auxiliary system to serve the critical smaller load when the central plant is shut down or otherwise would not be needed.

c. Individual reciprocating machines will not exceed 200 tons capacity, and the total capacity of all reciprocating machines or packaged air-conditioning units equipped with reciprocating compressor used for air conditioning a single facility will not exceed 400 tons. Refrigerant compressors of the reciprocating type will have at least three stages of capacity reduction. A single packaged unit will not contain more than eight compressors.

d. When a two-stage centrifugal compressor is selected, a refrigerant intercooler will also be required. For low temperature applications, where compressors with four or more stages may be needed, two stage intercoolers will be used. Use capacity control methods to reduce energy consumption as the load is reduced to minimize life cycle cost. Centrifugal type units will have a capacity control system providing for continuously variable capacities from 10 to 100 percent.

7-5. Chilled water distribution

The preferred method of distributing chilled water to the mission critical area(s) is to use dedicated chillers for these areas when continuous operation of these rooms is necessary and it is not economically feasible to run a building chiller(s) for 24 hours/day. The mission critical areas are supplied by dedicated chillers while a different chiller supplies the rest of the building. Refer to figure 7-1, Dedicated C4ISR chillers. It is then possible to provide a cross connection between the mission critical area chillers and the building chiller if additional backup and redundancy is desired. The use of dedicated chillers for the mission critical areas with another serving the remainder of the facility is more responsive to changing loads and expansion and offers the highest system reliability.

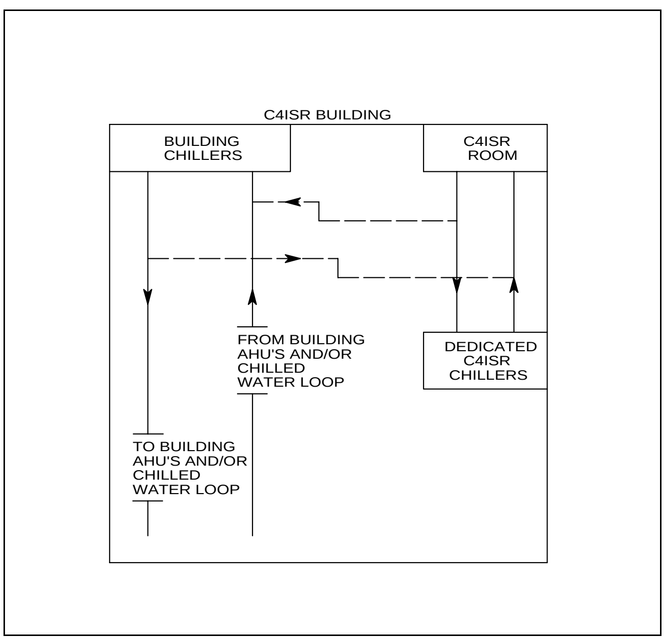

Figure 7-1. Dedicated C4ISR building

a. Other options for chilled water distribution are to use the building chillers for both the mission critical areas as well as the non-mission critical areas of the building. This configuration is commonly used when there are dedicated building chillers and the mission critical area load is relatively small and does not require dedicated chillers. Disadvantages to using only the building chillers would be the operating cost of running the building chillers 24 hours/day if the cooling load for the mission critical areas is relatively small. The system reliability is also not as good as with the use of dedicated chillers for the mission critical areas.

b. The use of central chiller plants for distributing chilled water to C4ISR facilities is another option. A central chiller plant may be considered when there are many buildings located relatively close to each other, or when it is not economically feasible to locate a chiller in each building. The disadvantages to using a central chiller plant are: the expense of operating a large chiller plant 24 hours/day to cool the mission critical areas; the additional EMP protection concerns associated with the central chillers and piping; and a lower degree of reliability due to possible damage, attack, or sabotage of the exposed piping.

c. The piping configuration serving the interior of the mission area(s) should be piped in a looped configuration with branch piping and valves connecting the computer room type air-conditioning units located inside the mission areas. The main piping loop may be located underneath the raised floor if there is adequate space under the raised floor and the chilled water piping would not interfere with computer wiring or air flow. See figure 7-2, Interior C4ISR room piping. If space underneath the raised floor is a concern, the piping loop can be located outside the room around the perimeter. The chilled water lines would penetrate the mission critical area walls where needed. Refer to figure 7-3, Perimeter C4ISR room piping. If the room is EMP shielded, a disadvantage to the outside perimeter pipe loop is that this arrangement requires either a larger shielded area or EMP treatment for all of the penetration points. The use of redundant piping should be considered when redundancy is required for critical operations, when a single failure in a pipeline could impact mission operations, or when future growth is anticipated.

7-6. Direct-cooled electronic equipment

Some electronic and computer equipment on the market requires cooling water to remove a portion or all of the heat generated within the cabinet. The cooling water system configuration within the cabinets will vary, but in almost all cases, the cooling media circulating within the cabinets will be distilled or demineralized water. Computers may be furnished with integral closed-loop cooling systems made up of demineralized water to chilled water heat exchanger and pump. If there is abundance of direct-cooled electronic equipment in the mission area that requires chilled water, consideration should be given to providing a dedicated chiller for the electronic equipment. When the direct-cooled equipment load is small and does not warrant a dedicated chiller, a tempering loop should be considered. In a tempering loop, the chilled water supply is blended with the return water until the desired water temperature required for the electronic equipment is met.

7-7. 15-minute back-up cooling capacity

In the event of a power failure, critical water-cooled electronic equipment and air handlers serving the mission critical areas must be provided with chilled water by a backup cooling system for at least 15 minutes. See figure 7-4, System for 15-minute backup cooling capacity. During this time, emergency diesel generators will be started and the chillers brought back online.

a. Under normal operation, chilled water from the chillers or a tempering loop (depending on equipment requirements) enters near the top of a chilled water storage tank and exits near the bottom of

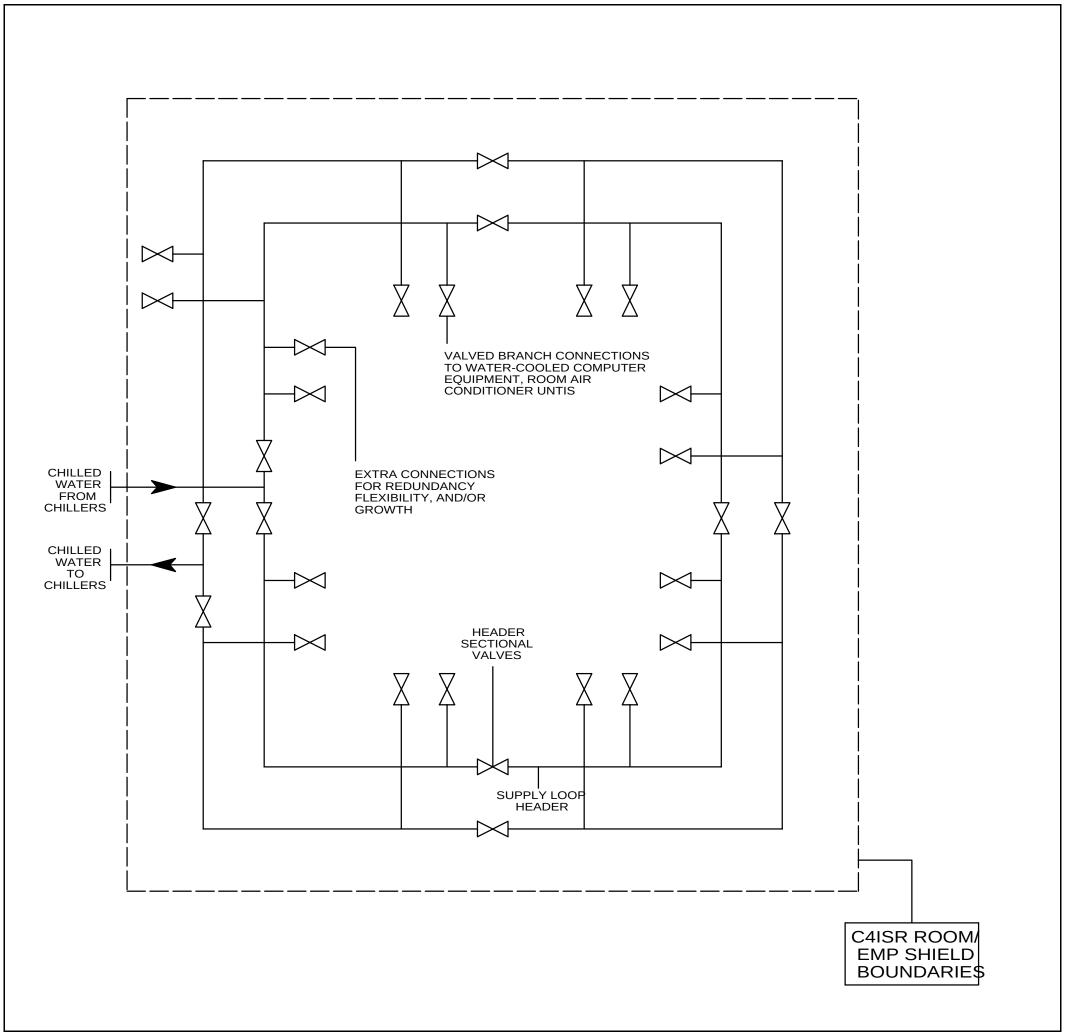

Figure 7-2. Interior C4ISR room piping

the storage tank. The chilled water then bypasses an emergency, circulating pump by going straight through a diverting valve to the computer room type air-conditioning units and electronic equipment in the mission areas. After cooling the equipment, the chilled water then passes straight through another diverting valve and back to the chillers.

b. In the event of a power failure, the emergency circulating pump, the computer room air-conditioning units, and controls will be started by the dedicated UPS. The diverting valves will cause chilled water flow to bypass the chillers, and the emergency circulating pump will circulate chilled water from the storage tank to the equipment.

c. The chilled water storage tank is sized to deliver 15 minutes of chilled water to the equipment should the power fail. The storage tank is insulated and designed to withstand system water pressures. The storage tank is usually sized for the maximum rise in chilled water temperature that the electronic equipment can tolerate. When power is restored and the chillers come back online, chilled water will be supplied to electronic equipment and computer room air-conditioning equipment at this elevated temperature until the storage tank has been recharged. By oversizing the storage tank, the rise in chilled water temperature can be minimized.

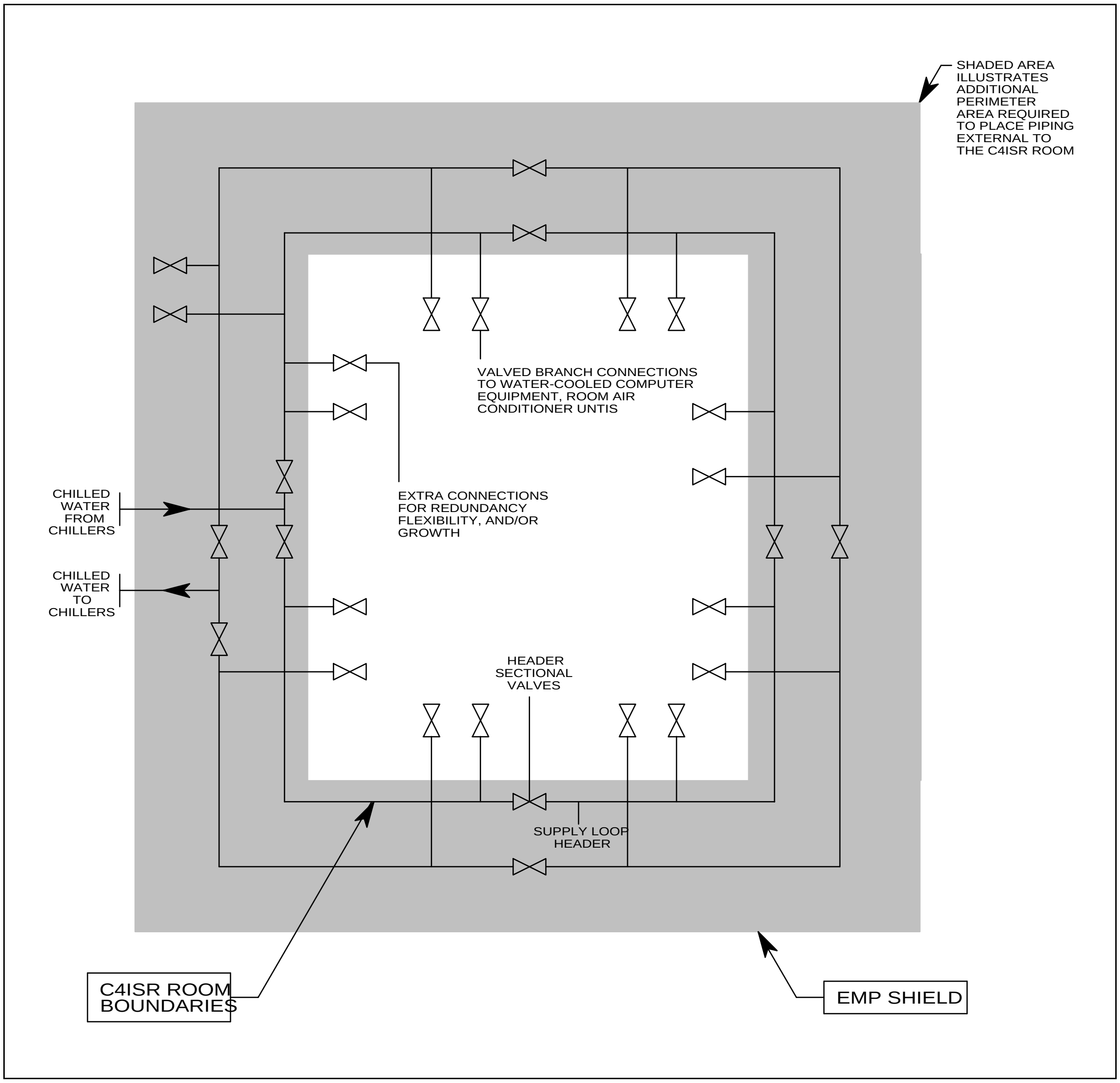

Figure 7-3. Perimeter C4ISR room piping

d. Another storage strategy involves installing a second tank on the return water side of the chillers. With this arrangement, when the chillers come back online, the warm return water passes through the chillers before being supplied to the electronic equipment and air-conditioning units. The use of this storage option depends on the criticality of the mission, cost constraints, and the chilled water temperature requirements of the electronic equipment.

7-8. Leak detection

Leak detection devices should be installed in the plenum beneath the computer room raised floor to warn of leaks in the cooling water lines. All critical functions such as water flow, pressure, and temperature should be monitored.

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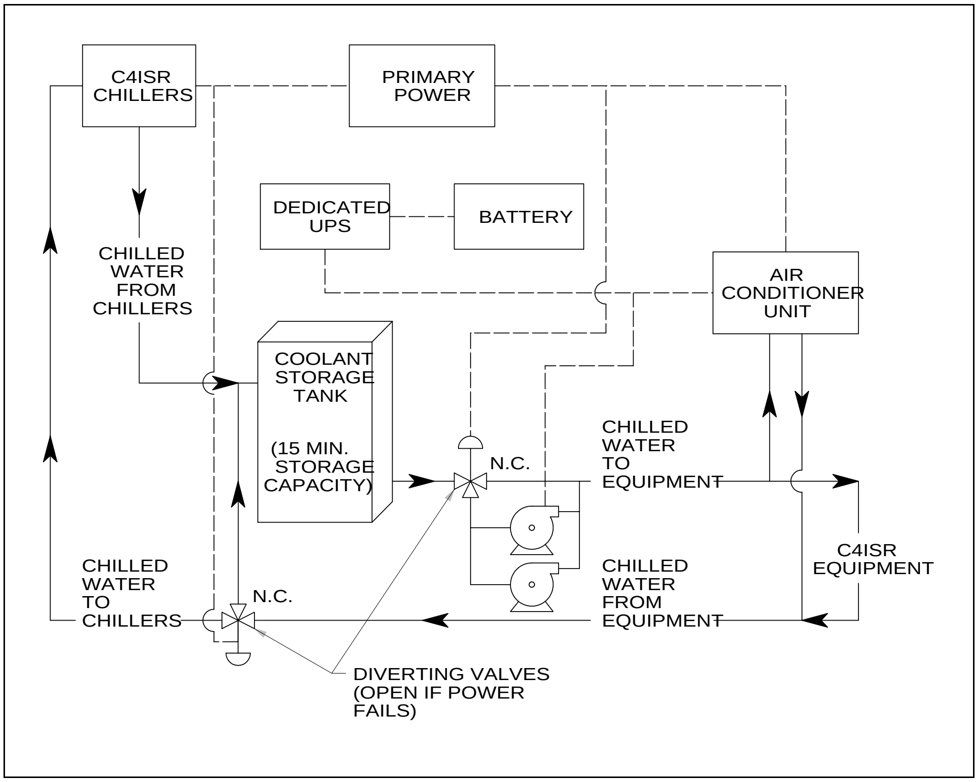

Figure 7-4. System for 15 minute backup cooling capacity

7-9. Electromagnetic pulse (EMP) protection

The penetrations to EMP shielding caused by air distribution systems are among the largest in the C4ISR facility. The design agency shall utilize the following criteria to ensure EMP protection is not compromised.

a. EMP protection for air distribution penetrations uses a honeycomb waveguide air vent panel. The waveguide must be made of a conductive material and must be continuously welded or soldered to the primary EMP shield so that current flowing on the waveguide can be discharged to the primary EMP shield. The maximum inside diameter of a penetration must be four inches or less to achieve a cutoff frequency of 1.47 GHz for a rectangular penetration and 1.73 GHz for a cylindrical penetration. The unbroken length of conducting material adjacent to the penetration must be a minimum of five times the diameter of the conducting material (i.e., pipe, duct) to attenuate by at least 100 dB at the required frequencies. Since, in general, ventilation duct dimensions cannot reasonably be limited within the four inch restriction, the duct itself cannot be used as the waveguide. As the term honeycomb implies, the cross sectional area of the panel is divided into a number of cells, each of which complies with the four inch maximum diameter and five diameter length requirements. The grid structure must be metallic and all joints must be continuously bonded. Honeycomb panels are commercially available in dimensions up to 18 x 18 inches. Larger panels can be made by soldering the seams of multiple panels. The honeycomb material is soldered into a steel frame, which is subsequently welded into the penetration plate or attached with radio frequency interference (RFI) gasketed and bolted seals.

b. The pressure drop across the honeycomb panel must be taken into account when designing the air distribution system and determining fan power requirements. Because of the small cell size, the panels tend to clog with dirt easily. Thus, filters and access for changing them should be incorporated into the design.

c. Another consideration is the EMP protection of controls for air distribution systems. Whenever possible, damper actuators and other air distribution controls should be located inside the C4ISR room shield. For air distribution controls located outside the C4ISR room shield, consideration should be given to installing pneumatic controls, which are not as susceptible to an EMP event as direct digital controls.

d. The air duct wave guide filter will be specified in terms of the attenuation over a specified range of frequencies and the allowable air pressure drop across the filter in accordance with TM 5-858-5, Designing Facilities to Resist Nuclear Weapons Effects: Air Entrainment, Fasteners, Penetration Protection, Hydraulic Surge Protection Devices, and EMP Protective Devices.

7-10. Chemical, biological, and radiological (CBR) protection

The commander or AHJ determines if facilities are susceptible to the CBR threat, which facilities and areas within the facilities require collective protection (CP) systems, and the class of protection required.

a. Class I CBR filtration units shall be provided at the direction of the commander or authority having jurisdiction. This class of protection is applicable against wartime military threats that produce a large-scale release of agents over an extended period of time. Effective protection requires a CBR filtration and overpressure system that resists a continual large-scale threat in a 40 km/hr (25 mph) wind. This corresponds to a minimum toxic-free area (TFA) over-pressure of 75 Pa (0.3 inch wg). The filtration and pressurization system may be operated continuously or maintained in a standby mode, i.e., energized only when there is a known threat of attack. An internal or external contamination control area and an ingress and egress airlock are required. For Class I facilities that cannot meet a carbon dioxide level of 0.1 percent, a carbon dioxide detector will be provided that will alarm at a level 50 percent higher than the expected carbon dioxide value, but not more than 0.8 percent. Normally, the filtered outside air required to pressurize the TFA will exceed the occupant ventilation rate. Where required, guidance on carbon dioxide absorption systems can be found in TM 5-858-7, Designing Facilities to Resist Nuclear Weapon Effects - Facility Support Systems.

b. Mission critical areas (i.e.,TFAs) shall be protected with Class II CBR filtration systems as a minimum. This class of protection is applicable to a terrorist attack with little or no warning that produces a short duration small-scale release of agent. Outside air intakes will be protected by continuously operating CBR filtration units. The filtration system will be sized for the normal facility air intake requirements and need provide little or no facility overpressure. The CBR filtration system will be required to provide an overpressure that prevents the penetration of agents through the TFA envelope at wind speeds of 12 km/hr (7 mph). An airlock for ingress and egress into the mission critical areas is not required, but a vestibule that acts as an airlock is desirable to maintain overpressure. An internal or external contamination control area is also not required for Class II facilities.

c. For Class II facilities, noticeable leakage paths should be sealed in existing facilities, and sealing measures should be incorporated in the design of new facilities. The TFAs will be designed for a minimum overpressure goal of 5 Pa (0.02 inches wg). This overpressure corresponds to a wind speed impact pressure normal to a wall of 12 km/hr (7 mph). This wind speed condition is most favorable for directing a plume of agent with minimum dispersion toward and outside air intake. After installation of the overpressure system, it is possible that a TFA pressure may be higher than the 5 Pa (0.02 inch wg). A higher pressure provides a higher factor of safety for the CP system and should not be intentionally lowered to maintain a 5 Pa (0.02 inch wg) over-pressure.

d. For existing facilities, the ventilation design will be analyzed to determine if an overpressure can be achieved by supplying additional air through the existing ventilation system, restricting exhaust airflow rates such as from an economizer air exhaust or from other building exhaust systems. The indoor air quality and exhaust airflow rates required by building ventilation codes will be maintained. If an overpressure can be achieved with the existing ventilation system, an air leakage measurement test using a blower door assembly will be performed in accordance with American Society for Testing and Materials (ASTM) E779, Standard Test Method for Determining Air Leakage Rate by Fan Pressurization. Leakage locations can be identified by physical inspection or with smoke testing. Leakage areas will be sealed with good quality sealant or, if necessary, reconstructed. If an overpressure cannot be achieved in existing facilities, good protection is still provided by protecting the outside air intakes.

e. For new facilities, a TFA minimum overpressure of 5 Pa (0.02 inch wg) can be achieved by supplying a higher rate of conditioned fresh air to the TFA than is exhausted. Care should be taken during design and construction to ensure that proper sealing of penetrations is performed and that continuous air leakage control barriers are used in the TFA envelope. A blower door test of the TFA envelope should be performed after construction to verify the leakage rate and ensure that the CP overpressure filtration system has sufficient capacity.

f. The HVAC systems and CBR filtration units shall be designed, operated, and maintained to provide uncontaminated air to the TFA (i.e., mission critical areas). Ductwork that serves the TFA during normal operations but is not required during CP operations will be closed off and isolated by use of low-leakage damper at the TFA envelope. Isolation damper position indicators will be included to provide visual identification of the open and closed position. Isolation dampers will be controlled from the control room and be visually annunciated in the control room.

g. Outside air intakes shall be secured to inhibit the direct insertion of contaminants. The outside air intakes shall be located in an inaccessible location or secured to inhibit the direct insertion of contaminants. The outside air intake rate per occupant will conform to American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) 62, Ventilation for Acceptable Indoor Air Quality.

h. The CBR filtration system shall be field leak tested by an independent testing agency after installation. The system should also be mechanically leak tested every 12 months and after replacement of the high efficiency particulate air (HEPA) filter or adsorption filter. The design must ensure that adequate filter access is provided.

i. The CP filtration units shall be located in a CBR mechanical room. If the CP filtration system is located in a potentially contaminated environment, i.e., outside the TFA envelope, the CP filtration system will be designed as a blow-through system with the CBR blower located before the CP filtration system. If the CP filtration system is located in a clean environment, i.e., inside the TFA envelope, and draws in the contaminated air through a ductwork system, it will be designed as a draw-through system with the CBR blower located after the CP filtration system. Upon a loss of commercial power, the CBR blower(s) shall be powered from the UPS system until the emergency generators can be brought online.

j. The blower total static pressure of the CP filtration system will be designed to include the filtration system with dirty filters, ductwork system pressure losses, and the overpressure requirement of the TFA. The filtration system is the most critical part of the CP system. A number of filtration systems are available from both the military and commercial suppliers. If commercial filter systems are used, the mechanical system designer should have the technical expertise to prepare specifications that meet military filter system requirements. Military filtration units are typically provided as government-furnished equipment (GFE). Military equipment provided as GFE has the advantage of being pre-approved for use on Government installations, while commercially available equipment requires additional Government quality testing. The military filtration unit does not provide air tempering of the filtered air. For Class I and II facilities, the filtered air can be either ducted directly into the facility air handling unit(s) return ductwork or discharged directly into the TFA. If the CBR filtration units are ducted to the air handling unit(s) return ductwork, the air handling unit(s) provides tempering of the air and must be located within the TFA envelope. Air tempering will be required if the filtered air is discharged directly into the TFA. For continuously operated filter systems, accessory equipment such as moisture eliminators and large particulate filters shall be considered for protection of the filter system.

k. In a typical system, fresh air is drawn via a tunnel or shaft through an air filter of the conventional type and a CBR filter, and then is drawn through a tempering coil. At least two air intakes will be provided whenever possible and given a maximum separation to reduce the possibility of being damaged or destroyed. N + 2 standby CBR filter units will be installed for occasions when the filters become contaminated and require replacement and when such replacement cannot be accomplished by shutting down the fresh air supply. The conditioned outside air is ducted to various rooms or zones where zone air handling units will mix the fresh air and return air and condition the air prior to distribution to the conditioned spaces.

l. A separate CBR filter equipment room will be provided for the air filtering equipment. The room will be pressurized with clean air and the filter units and fans will be arranged so that any leakage into the room will be that of clean air. Refrigeration compressors and evaporative condensers of any air-conditioning system will be placed outside the CBR filter equipment in order to reduce the heat buildup, filtered air requirements, and possible refrigerant leakage. The CBR filter units will be installed in a readily accessible location and be provided with an overhead hoist for periodic removal and replacement. The CBR filter units will be located as close as possible to an exit and remote from the occupied portions of the structure.

7-11. Administration areas

Generally, administrative areas will be air conditioned only in locations where the outside dry bulb temperature in 26.7°C (80°F) or higher for over 350 hours per year. Central station air handling units, self-contained packaged units, and fan coil units can be used in non-mission critical areas of the facility. The use of self-contained air conditioners, one for each room or zone, simplifies the zoning and control problems, improves the overall reliability, and avoids the use of large, long, insulated ducts. Self-contained air conditioners will typically be chilled water units using water from a chiller, water-cooled units using tower water, or direct-expansion (DX) units. Fresh air will be ducted to the return side of the self-contained air conditioner. This allows tempering of the outside air before entering the occupied space. Self-contained air conditioners can be furnished with hot water, steam, or electric coils when heating is required.

7-12. Generator room\building heating, ventilating, and air conditioning and combustion air

The HVAC system for the generator room or generator building shall meet the requirement of NFPA 110, Emergency and Standby Power Systems.

a. For the emergency generator equipment room, the ventilation or air-conditioning equipment, or both, shall be sized so that the space temperature does not exceed the generator manufacturer's maximum allowable temperature. Consideration shall be given to properly sizing the ventilation or air-conditioning systems to remove the heat rejected to the emergency generator equipment room by the energy converter, uninsulated or insulated exhaust pipes, and other heat-producing equipment.

b. The HVAC system for the generator room or building shall be designed to avoid hazards due to potentially explosive vapors. Ventilation openings and openings for installation and removal of materials and equipment shall be provided for the generator room or building.

c. Provisions shall be made to maintain the generator equipment room at not less than 70°F. Where engine water jacket heaters are used, the generator equipment room can be maintained at not less than 40°F.

d. During operation, prime movers require a constant supply of large quantities of air for combustion of fuel. Adequate combustion air shall be supplied to the emergency generator equipment. The combustion air is usually supplied via louvered or ducted ventilation opening to the room or building. Each generator set shall be provided with a separate combustion air intake. Combustion air for diesel generators shall come from an air intake structure separate from the air intake for personnel. The combustion air intake shall be filtered. Dampers and louver restrictions shall be considered in sizing the room ventilation requirements.

e. Precautions must be taken when environmental conditions related to location of the generating system are extreme (such as tropical heat and/or desert dryness and dust). Cooling towers and special air filters are usually provided to combat these conditions. Arctic conditions require special heating requirements.

7-13. Generator exhaust system

The exhaust system equipment and installation, including piping, muffler, and related accessories, shall be in accordance with NFPA 37, Stationary Combustion Engines and Gas Turbines, and NFPA 110. Chimneys, where required, shall be constructed and installed in accordance with NFPA 211, Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances. Exhaust pipes shall be installed with clearances in accordance with NFPA 37. The generator exhaust shall meet the local/EPA emission requirements.

a. Generator exhaust gases shall be discharged to the outside by piping. Exhaust pipe(s) shall terminate outside the structure at a point where the hot gases or sparks will be discharged harmlessly. The piping shall terminate in a rain cap, tee, or ell, pointing downwind from the prevailing wind. The exhaust piping shall terminate in such a manner that toxic fumes cannot re-enter a building or structure.

b. Each generator set shall be provided with a separate exhaust system. The exhaust system shall be designed so it does not create excessive backpressure on the engine. Engine exhaust systems shall be designed on the basis of flue gas temperatures. Exhaust pipes shall be of wrought iron or steel and of sufficient strength to withstand the service.

c. Exhaust piping shall be connected to the prime mover by means of a flexible connector and shall be independently supported thereafter so no damaging weight or stress is applied to the engine exhaust manifold or turbocharger. A flexible connector shall be provided in the exhaust pipe from the engine to minimize the possibility of a break in the engine exhaust system because of engine vibration or thermal expansion.

d. The exhaust system shall be equipped with an adequate muffler or silencer, spark arrestor, and rain cap. The muffler shall be placed as close as practical to the engine, in a horizontal position where possible.

e. Exhaust pipes and flexible connectors shall not permit the release of dangerous gases, sparks, or flames into the generator room. The exhaust system installation shall be gastight to prevent exhaust gas fumes from entering inhabited rooms or buildings.

f. Low points in the exhaust systems shall be provided with suitable means for draining condensate. A condensate trap and drain valve shall be provided where necessary at the low point of the exhaust piping.

g. The exhaust system shall not pass near any flammable material. An approved thimble shall be used where exhaust piping passes through combustible walls or partitions. Consideration shall be given to a fire resistive, high temperature rated, insulating material wrapped around the exhaust system that is covered with a metal retainer to reduce heat radiation and exhaust noise. Exhaust systems shall be guarded to prevent personnel burns.

7-14. Uninterruptible power supply (UPS) room

The HVAC system for the UPS room shall comply with NFPA 111, Stored Electrical Energy Emergency and Standby Power Systems.

a. The UPS system's inverter, converter, switches, and controls shall be located in an area provided with sufficient heating and air conditioning to ensure that, both during the time that normal power is available and during an emergency, the equipment is operated within the manufacturer's ambient temperature specifications. Many UPS systems are designed to operate over the temperature range of 50^{o}F to 104^{o}F and a relative humidity from 5 to 95 percent.

b. For small UPS systems located within mission areas, ventilation with a minimum of two air changes per hour shall be provided to remove gases generated by vented batteries during charging or caused by an equipment malfunction.

c. For UPS equipment using free electrolyte batteries with vents that allow the free evolution of gases, ventilation openings or airflow shall be situated to limit the possibility of the buildup of gas pockets. Where needed, fans used to circulate and exhaust air shall use explosion proof motors designed for the application. (NFPA 70, See article 480, National Electrical Code.)

7-15. Uninterruptible power system battery room ventilation

The UPS batteries shall be isolated in a separate battery room that shall be ventilated. The ventilation system shall include sensors for initiating alarm signals to the central control room in the event of ventilation system failure. Design of the battery room shall meet the requirements of NFPA 70, article 480.

a. The battery room shall be ventilated by means of two exhaust fans. Fans arranged in parallel shall be controlled so that one is operating at full flow and the other is on stand-by. The stand-by fan will be automatically started upon failure of the normally running fan. Upon loss of commercial power, the battery room ventilation fans and their controls will be powered from the emergency generators. Each fan shall have an independent failure alarm.

b. Size the battery room ventilation system to prevent hydrogen concentration in the room from exceeding 2 percent by volume. The hydrogen (H_2) ventilation system for the battery room shall be separate from ventilation systems for other spaces. Air recirculation in the battery room is prohibited. The fan motors must be outside the duct and battery room. Each fan will have a non-sparking construction. Size the exhaust fans as follows:

Q = 0.054 x I x N (Reference: TM 5-810-1, Paragraph 4-8)

Where:

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

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

N = (number of batteries to be recharged at one time) x (number of cells per battery).
(Note: A single cell is normally two volts DC. Therefore, a six volt battery normally has three cells and a 12 volt battery normally has six cells.)

c. Areas used for battery storage in maintenance areas will be designed for sufficient diffusion and ventilation of gases from the battery to prevent the accumulation of an explosive mixture.

d. Sealed batteries are less tolerant of high temperatures than are wet type (i.e., vented) batteries. If average daily temperatures in the battery room exceed 92^{o}F, consideration should be given to using only wet type batteries.

7-16. Fuel storage area ventilation

Provision shall be made for adequate ventilation of fuel storage areas prior to entering for inspection or repair. Ventilation for fuel storage areas shall comply with NFPA 30, Flammable and Combustible Liquids Code, NFPA 37, and NFPA 110.

7-17. Heating systems

The major requirement for heating during normal operation will be heating fresh air to interior design conditions and for reheating. The greatest disadvantages of combustion type boilers are space, combustion air, and flue gas requirements that eliminate them from consideration for underground service. For aboveground facilities, fuel and ash handling requirements render coal-fired boilers unsuitable but oil-fired package boilers are acceptable for aboveground service. In industrial facilities where process steam is required, medium or high pressure steam boilers are recommended. Electrically heated steam boilers are suited for C4ISR facilities having a large demand for humidification steam in the wintertime.

a. The type, number, and size of heating units or plants to be used for a new or conversion facility will be based on a thorough evaluation of the heating requirements for the anticipated life of the buildings to be constructed and served. Consideration will be given to interconnecting existing central plant systems or large building systems to supply new building requirements. All fuel-burning facilities will meet national pollution emissions requirements and applicable state and local requirements. The Director of Public Works (DPW) will review and approve all proposed connections, extensions, alterations, or attachments to a building’s heating system.

b. Space heating temperature standards will be in accordance with the AR 11-27, Army Energy Program.

c. For the operation, maintenance, and safety of boiler heating plants, the installation commander will determine the length of the heating season, based on local conditions, for providing heat to facilities requiring personal comfort. Central boiler and heating plant and building mechanical room equipment, outside distribution systems, and the main distribution systems in buildings will be marked with color banding and/or titles in accordance with American National Standards Institute (ANSI) A13.1, Scheme for the Identification of Piping Systems.

d. Water heating and storage tank capacities for domestic hot water supply will be in accordance with the U.S. Army Corps of Engineers architectural and engineering instructions (AEI) and the National Standard Plumbing Code.

e. Heat distribution systems for 201^{o}F and above will be designed in accordance with TM 5-653, Steam Hot-Water and Gas Distribution Systems: Inspection and Preventive Maintenance Services, and will be selected in the following order of preference:

(1) Above ground

(2) Shallow concrete trench

(3) Direct buried

7-18. Boilers

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

a. Provide adequate room, connections, piping, etc., in boiler installations where future expansion is likely. This will allow boilers and related auxiliaries anticipated for future loads to be added as necessary.

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

c. The installation of combustion equipment, including burners and draft fans, will be in accordance with ASHRAE Handbooks, Underwriters Laboratories (UL), NFPA, and the recommendations of equipment manufacturers.

d. All gas-fired equipment will be equipped with a burner, which can be readily converted to burn an alternate fuel, as required by AR 420-49, Utility Services. Specify gas equipment for dual fuel capability.

e. Provide gas and oil meters for the boiler installation. Provide a gas meter at each building. Install oil meters in both the supply line and the return line of each storage tank. All building steam supply, hot water supply, condensate return, and hot water return lines will be metered.

f. The combustion air requirement for steam and hot water boilers used for heating and domestic hot water loads may be combined with the personnel outside air requirements.

g. The boiler exhaust shall meet the local/EPA emission requirements.

7-19. Water treatment

The local water composition is essential to the design of water treatment for mechanical systems. A water analysis may be available from the using agency. If an analysis is unavailable, obtain a sample of the raw water. Test the sample and include the results in the applicable contract specifications. Design water treatment systems for boilers in accordance with TM 5-650, Repairs and Utilities: Central Boiler Plants. Condensate return line corrosion control will be selected in accordance with TM 5-650. Provide water treatment systems for cooling towers for prevention of corrosion, scale, and biological formations. In most cases, a water treatment is required for closed chilled water systems, hot water systems, and dual temperature systems.

7-20. Fire protection

The HVAC system shall be provided with a fire damper and smoke detection systems in accordance with NFPA 90A, Installation of Air Conditioning and Ventilation Systems. The HVAC system for multi-story facilities shall be equipped with a smoke control system that includes smoke dampers and smoke evacuation devices in accordance with NFPA 92A, Smoke-Control Systems. The battery room ventilation system shall be equipped with a signaling device that transmits a trouble signal to the control room when the concentration of H_2 in the room exceeds the control limit. Air filters for use in air-conditioning systems shall be noncombustible. All duct insulation and linings, including vapor barriers and coatings, shall be noncombustible.

7-21. Mechanical and electrical equipment rooms

HVAC requirements for mechanical and electrical equipment rooms are described below.

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

b. Chiller rooms. Rooms containing chillers shall be ventilated and provided with refrigerant monitors in accordance with ASHRAE 15, Safety Code for Mechanical Refrigeration.

c. Air conditioning. Air conditioning for equipment rooms may be provided where life cycle cost effective to prevent severe corrosion in salt laden areas where, during the six warmest consecutive months, the wet bulb temperature is 22.77°C (73°F) or higher for over 4,000 hours.

7-22. Toilets, lockers, and utility closets

Maintain these areas at a negative pressure relative to adjacent areas by exhausting air transferred from adjacent areas to the outdoors.

7-23. Vestibules

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

7-24. Economic and life cycle cost (LCC) considerations

The selection and operation of equipment within a C4ISR facility are governed primarily by requirements other than economy. The economics of equipment selection and operation may be compromised where dictated by facility mission requirements. The HVAC designer will attempt to balance space allocation, energy consumption, and optimum hardness design to ensure successful completion of the facility mission.

a. Trade-offs may be required to be made in efficiency and noise when using smaller ducts with higher velocities and small high capacity equipment such as fans, coils, and boilers. Noise will be kept within limits set by OSHA; however, for each space, and where necessary, such design consideration as grouping and isolation of equipment and noise attenuation will be provided for maximum utilization of space.

b. Where possible, the designer will evaluate for all non-mission critical areas and systems energy conservation items that appear to have potential for saving. Such items as heat recovery for HVAC and service water heating, economizer cycles, thermal energy storage, desiccant dehumidification, plastic door strips for loading docks, etc., should be considered. Include those items in the design that are life cycle cost effective.

7-25. Filters

To increase the useful life of high efficiency filters, prefilters will be installed. Prefilters will also be installed upstream of the tempering coils to eliminate dust buildup downstream. Special electrostatic or other types of self-cleaning filters are not recommended; conventional disposable units are preferred.

7-26. Coils and piping

Various coils and piping components are used in HVAC systems to control temperature and humidity.

a. Tempering coils are normally installed in makeup air units. The tempering coils are used to heat the outside air in winter to prevent condensation on ducts and to prevent freeze-up of heating and cooling coils in downstream air handling units. Steam tempering coils include tubes of the steam distributing type, mounted vertically, with full steam pressure on the coils at all times. Face and bypass dampers controlled by a downstream duct-mounted thermostat, will be used for controlling the tempered air temperature. Hot water tempering coils, utilizing a heat exchanger to maintain water temperature, a coil pump to maintain flow, and thermostatically controlled face and bypass dampers can function successfully in extreme weather with proper controls and alarms. A mixture of water and antifreeze will be circulated through the coils to minimize the possibility of coil freeze-up should the controls or pump fail.

b. Each facility will be zoned and provided with self-contained or built-up air handling units for cooling and dehumidification. For underground facilities, the primary problem is one of dehumidification and reheat. Both cooling and reheat coils will be provided for underground facilities.

c. Use of chilled water in unit air conditioners for individual rooms or zones has the advantage of simplicity and flexibility of control. Chilled water lines that pass through spaces with high dew points or are air conditioned will be insulated to prevent condensation. Heating coils can be installed in the air-conditioning units along with the cooling coils. For mission critical areas of the facility, a loop-type system of chilled water distribution will be provided with necessary valving to isolate loop segments in the case of failure of a portion of the system. Flexible connectors, vibration eliminators, and expansion joints will be utilized to connect piping to HVAC equipment that is subject to movement.

7-27. Refrigerants

Carefully review current Federal regulations prior to selecting mechanical refrigeration equipment. Current and anticipated future restrictions limit or prohibit using ozone-depleting substances. All design will comply with ASHRAE 15.

7-28. Fans

Fan selection and installation depends upon a variety of factors including the application, space availability, and noise considerations.

a. When space is not a factor, centrifugal fans with backward curved and air-foil type blades will be used for maximum efficiency. Vaneaxial fans are used when space is at a premium and nonturbulent inlet conditions can be obtained. The use of inlet vane straightness for this purpose in recommended.

b. Noise is of major importance in a closely occupied structure. Ductwork and fan mounts will be carefully designed. Ducts will be connected to fan and filter inlets and outlets by means of butyl rubber or butyl coated nylon cloth materials. Main supply fans should be remote from occupied areas and provided with resilient sound-absorbing bases. Noise due to high velocity ducts, abrupt turns, and rigid connections to fans will all be considered. Where high-velocity minimum-size equipment must be used, an adequate acoustical and vibration treatment will be employed.

7-29. Duct systems

Ducts that may carry contaminated air or run through areas that may become contaminated will be gas tight. Duct systems will be designed within prescribed limits of available space, friction loss, noise level, heat loss or gain, and pressure containment. Both high velocity and low velocity duct systems will be designed in accordance with ASHRAE Fundamentals Handbook. A low-velocity duct system using rectangular ductwork is practical in facilities where space is of secondary importance. A high-velocity duct system is often most practical in a facility where space is at a premium. Ducts will be constructed in accordance with applicable Sheet Metal and Air Conditioning Contractors National Association (SMACNA) standards. Air ducts serving other non-mission critical rooms shall either not pass through the mission critical area(s) or fire dampers shall be provided in the ducts.

7-30. Maintenance and testing

Adequate space to access items that require maintenance, such as filters, coils and drain pans, fans, strainers, etc. will be provided. Systems with features necessary for successful testing, adjusting, and balancing and for scheduled maintenance shall be provided with appropriate access.

7-31. Controls

Design HVAC controls in accordance with TM 5-815-3, Heating, Ventilation and Air Conditioning (HVAC) Control Systems.

7-32. Noise and vibration control

Design HVAC systems with respect to noise and vibration control in accordance with TM 5-805-4, Noise and Vibration Control. Use acoustical duct liner only where other methods of noise control are not feasible.