

**TM 5-691**

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**TECHNICAL MANUAL**

**UTILITY SYSTEMS DESIGN  
REQUIREMENTS FOR COMMAND,  
CONTROL, COMMUNICATIONS,  
COMPUTER, INTELLIGENCE,  
SURVEILLANCE, AND  
RECONNAISSANCE (C4ISR)  
FACILITIES**

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**HEADQUARTERS, DEPARTMENT OF THE ARMY**

**27 DECEMBER 2006**

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Technical Manual

HEADQUARTERS  
DEPARTMENT OF THE ARMY  
Washington, DC, 27 December 2006

No. 5-691

**APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED****UTILITY SYSTEMS DESIGN REQUIREMENTS FOR COMMAND,  
CONTROL, COMMUNICATIONS, COMPUTER, INTELLIGENCE,  
SURVEILLANCE AND RECONNAISSANCE (C4ISR) FACILITIES****CONTENTS**

	<i>Paragraph</i>	<i>Page</i>
CHAPTER 1. INTRODUCTION		
Purpose	1-1	1-1
Scope	1-2	1-1
References	1-3	1-1
Objectives	1-4	1-1
CHAPTER 2. SYSTEMS ENGINEERING AND SYSTEMS SAFETY		
General systems considerations	2-1	2-1
Program elements	2-2	2-1
Systems engineering database	2-3	2-2
Reliability and availability (R/A)	2-4	2-3
Life-cycle cost analysis	2-5	2-3
Operational control concept	2-6	2-3
CHAPTER 3. DESIGN CONSIDERATIONS FOR OPERATIONS AND MAINTENANCE		
General design considerations	3-1	3-1
Historical records	3-2	3-1
Maintenance concept	3-3	3-1
Evaluations	3-4	3-2
Operations and maintenance documentation	3-5	3-2
Verification	3-6	3-3
CHAPTER 4. CIVIL AND SITE ENGINEERING AND WASTEWATER AND STORM WATER MANAGEMENT		
General civil, site, and waste management design	4-1	4-1
Site development	4-2	4-1
Sanitary wastewater collection systems	4-3	4-3
Storm water management systems	4-4	4-5
CHAPTER 5. STRUCTURAL AND ARCHITECTURAL DESIGN		
General structural and architectural design	5-1	5-1
Foundation design	5-2	5-1
Functional layout	5-3	5-1
Exterior walls and roofs	5-4	5-2
Floors and floor finishes	5-5	5-2
Acoustical treatment	5-6	5-2

**This manual supersedes TM 5-691 dated 15 December 2000**

	<i>Paragraph</i>	<i>Page</i>
Life-safety	5-7	5-2
Eye washes and showers	5-8	5-2
CHAPTER 6.		
FIRE PROTECTION SYSTEMS		
General fire protection system design	6-1	6-1
Authority having jurisdiction (AHJ)	6-2	6-1
Services and qualifications of fire protection engineer	6-3	6-1
Specifications	6-4	6-1
General design requirements	6-5	6-1
Special protection systems	6-6	6-3
Water supply pressure requirements	6-7	6-3
Quantities of water required	6-8	6-4
Sources of water supply	6-9	6-4
Water distribution and storage	6-10	6-4
Fire pumps	6-11	6-5
Mission areas	6-12	6-6
Mission administration	6-13	6-7
Generator set area	6-14	6-7
Switchgear and uninterruptible power supply areas	6-15	6-8
Battery room	6-16	6-8
Control room (CR)	6-17	6-9
Data and power cabling areas	6-18	6-9
Fuel storage area	6-19	6-9
Loading/unloading areas	6-20	6-10
Entry control points	6-21	6-10
Transmit/receive stations	6-22	6-10
Transformer vault room	6-23	6-10
Generator sump	6-24	6-11
Cooling towers	6-25	6-11
CHAPTER 7.		
HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS		
General heating, ventilating, and air-conditioning (HVAC) design	7-1	7-1
Heating, ventilating, and air-conditioning (HVAC) equipment reliability and survivability	7-2	7-2
Mission critical areas and control room (CR)	7-3	7-2
Chillers	7-4	7-3
Chilled water distribution	7-5	7-4
Direct-cooled electronic equipment	7-6	7-5
15-minute back-up cooling capacity	7-7	7-5
Leak detection	7-8	7-7
Electromagnetic pulse (EMP) protection	7-9	7-8
Chemical, biological, and radiological (CBR) protection	7-10	7-9
Administration areas	7-11	7-11
Generator room/building heating, ventilating, and air-conditioning and combustion air	7-12	7-11
Generator exhaust system	7-13	7-12
Uninterruptible power supply (UPS) room	7-14	7-13
Uninterruptible power supply battery room ventilation	7-15	7-13
Fuel storage area ventilation	7-16	7-14

	<i>Paragraph</i>	<i>Page</i>
Heating systems	7-17	7-14
Boilers	7-18	7-15
Water treatment	7-19	7-16
Fire protection	7-20	7-16
Mechanical and electrical equipment rooms	7-21	7-16
Toilets, lockers, and utility closets	7-22	7-17
Vestibules	7-23	7-17
Economic and life cycle cost (LCC) considerations	7-24	7-17
Filters	7-25	7-17
Coils and piping	7-26	7-17
Refrigerants	7-27	7-18
Fans	7-28	7-18
Duct systems	7-29	7-18
Maintenance and testing	7-30	7-18
Controls	7-31	7-19
Noise and vibration control	7-32	7-19
CHAPTER 8.	PIPING SYSTEMS	
	General piping systems design	8-1
	Piping systems reliability and survivability	8-2
	Specifications	8-3
	Cooling water systems	8-4
	Fuel systems	8-5
	Air start systems	8-6
	Instrument air systems	8-7
	Lube oil systems	8-8
	Water treatment	8-9
	Corrosion protection	8-10
	Protection	8-11
	Water distribution system	8-12
	Potable (domestic) water supply	8-13
	Eye washes and safety showers	8-14
	Process water supply	8-15
	Plumbing and sanitary sewer systems	8-16
	Storm and process drains	8-17
	Condensate drains	8-18
	Cooling tower blow down and drains	8-19
	Seepage and sump collection	8-20
	Insulation	8-21
	Water storage tank	8-22
	Pressure vessel	8-23
	Valving	8-24
	Piping systems maintenance	8-25
	Piping above computer and electronic equipment areas	8-26
CHAPTER 9.	EMERGENCY GENERATOR SYSTEMS	
	General mechanical systems design	9-1
	Generator room or building	9-2
	Diesel engine cooling systems	9-3
	Engine coolant heaters	9-4

**TM 5-691**

	<i>Paragraph</i>	<i>Page</i>
Lubrication system	9-5	9-3
Engine protection	9-6	9-4
<b>CHAPTER 10. ELECTRICAL SYSTEMS</b>		
General electrical design	10-1	10-1
Electrical systems maintenance	10-2	10-6
Power quality	10-3	10-6
Off-site electrical power	10-4	10-7
On-site power generation equipment	10-5	10-10
Load shedding and restoration	10-6	10-14
Exterior distribution system	10-7	10-15
Facility electrical distribution system	10-8	10-15
Unit substations	10-9	10-16
Motor control centers and distribution panels	10-10	10-19
Automatic transfer switches	10-11	10-19
Interior distribution systems	10-12	10-19
Lighting and receptacle systems	10-13	10-19
Direct current systems	10-14	10-20
Uninterruptible power supply (UPS) systems	10-15	10-21
Grounding system	10-16	10-25
Lightning protection	10-17	10-27
Communications and alarms	10-18	10-28
Electromagnetic interference/radio frequency interference	10-19	10-30
Personnel and electrical system protection	10-20	10-31
Cathodic protection	10-21	10-31
<b>CHAPTER 11. INSTRUMENTATION AND CONTROL SYSTEMS</b>		
General instrumentation and control design	11-1	11-1
Supervisory control and data acquisition system	11-2	11-1
Power loss and restoration	11-3	11-1
Automatic control functions	11-4	11-1
Control room instrumentation	11-5	11-2
Instruments and controls for power generation equipment	11-6	11-3
Local instrumentation	11-7	11-3
Transient protection, grounding, bonding, and shielding	11-8	11-3
<b>APPENDIX A. REFERENCES</b>		
<b>GLOSSARY</b>		

**LIST OF FIGURES**

<i>Figure</i>	<i>Title</i>	<i>Page</i>
Figure 7-1	Dedicated C4ISR building	7-4
Figure 7-2	Interior C4ISR room piping	7-6
Figure 7-3	Perimeter C4ISR room piping	7-7
Figure 7-4	System for 15-minute backup cooling capacity	7-8
Figure 8-1	Piping and instrumentation diagram legend	8-2
Figure 8-2	Typical cooling water flow & instrumentation diagram	8-4
Figure 8-3	Typical diesel fuel flow & instrumentation diagram	8-7
Figure 8-4	Typical starting air flow & instrumentation diagram	8-10
Figure 8-5	Typical instrument air flow diagram	8-11
Figure 9-1	Typical diesel engine liquid cooling system with radiator	9-2
Figure 9-2	Typical diesel engine lubrication system	9-4
Figure 10-1	Hierarchy of electrical loads	10-1
Figure 10-2	Small capacity power system	10-3
Figure 10-3	Medium capacity power system	10-4
Figure 10-4	Large capacity power system	10-5
Figure 10-5	C4ISR site primary substation	10-9
Figure 10-6	Generator protection system	10-13
Figure 10-7	DC power distribution	10-17
Figure 10-8	Double ended substation	10-18
Figure 10-9	Typical design goals of power-conscious computer manufacturers	10-23

**LIST OF TABLES**

<i>Table</i>	<i>Title</i>	<i>Page</i>
10-1	System grounding sub-application	10-26
10-2	Ground electrode impedance applications	10-27
11-1	Automatic control functions	11-2
11-2	Minimum CR control panel instrumentation for prime movers	11-4
11-3	Monitoring and control functions of engine control panel	11-4
11-4	Functions to be controlled locally	11-5

# CHAPTER 1

## INTRODUCTION

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### 1-1. Purpose

This manual establishes minimum requirements and design objectives for utility systems supporting major fixed Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) facilities. The existence of the manual does not, in itself, authorize upgrade or modifications of existing C4ISR facilities solely to meet these requirements. Facilities required to fully comply with the provisions of the manual will be designated by the Joint Chiefs of Staff, a Military Department Headquarters, or a Major Command.

### 1-2. Scope

This manual shall be used in the engineering design, fabrication, and installation of specifically designated fixed ground-based facilities in a threat-hardened C4ISR network. Minimum performance requirements are prescribed for the design of highly reliable utility systems that will permit C4ISR operation free from man-made threats. This manual applies to both new construction and to retrofit of existing facilities. Use of the manual for threat protection of other ground-based communications-electronics facilities that require high reliability is also encouraged. There are three basic sizes of C4ISR installations for which the requirements of this manual are applicable. See chapter 10 for the electrical requirements for each of these installation types.

- a. First is a small C4ISR facility such as a remote telephone switch center, typically housed in a building of less than 1000 square feet of floor area. The power system requirements will be less than 250 kVA.
- b. Second is an average C4ISR facility such as a main computer/communication center, typically housed in a building of 25,000 to 40,000 square feet of floor area. The power system requirements will typically not exceed 2500 kVA.
- c. Third is a C4ISR complex that consists of several buildings and a central distribution power plant. The power system requirements will generally be on the order of ten MVA or greater.

### 1-3. References

Appendix A contains a list of references used in this manual.

### 1-4. Objectives

Survivable C4ISR capabilities are essential to a credible military deterrent. This manual supports threat-survivability objectives by providing standardized, highly reliable utility systems for support of fixed ground-based facilities in a threat-hardened C4ISR network. These uniform requirements ensure balanced threat hardening for all critical facilities in the network.



## CHAPTER 2

# SYSTEMS ENGINEERING AND SYSTEMS SAFETY

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### 2-1. General systems considerations

Requirements are presented in this manual for the design of optimally reliable, safe, self-contained C4ISR utility systems and for the design of conventional electrical power and other utility services. These utility systems shall be capable of supplying services continually to the C4ISR installation site during any natural or man-made disruption in commercial services. Off-site power facilities are assumed to be adequate to supply peak power demands, but are not assumed to be uninterruptible. Potential threats include physical attacks; biological, chemical, and radiological warfare; and close-in and high-altitude nuclear blasts.

### 2-2. Program elements

The essential elements of a system's engineering program are described below. They shall be considered in light of the organization's mission and function; the availability of existing natural and manmade resources and the security necessary for a new or existing facility.

- a. Reliability, availability, and maintainability (RAM) requirements shall be implemented during design by the design agency to maximize the availability of the C4ISR utility systems.
- b. Human factors engineering (HFE) activities will ensure that reliability, availability, and safety of the C4ISR power system are not degraded through human activities during operation or maintenance. The design agency shall accomplish the HFE program requirements through the use of established standard HFE design criteria and practices based on MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities.
- c. The C4ISR power system safety program shall ensure that the design incorporates, within program restraints, the highest attainable level of inherent safety. It shall eliminate or reduce the probability of events that can cause injury or death to personnel, or damage to or loss of equipment or property. For example, pipes, lines, and tanks shall be placed away from high-traffic areas. Safety documentation shall be provided for safety items that require designation or may cause action during subsequent program phases. The design agency system safety program shall be based on a philosophy that the most effective actions to control potential hazards are those taken early in the design process.

(1) When hazards cannot be controlled by design measures, including safety and warning devices, special operating procedures shall be developed and documented. The safety program shall provide support to the systems engineering (SE) program and shall ensure that the applicable requirements of MIL-STD-882, System Safety Program Requirements, are met.

(2) The systems safety program shall define and address the system safety analyses that shall be performed during development of design. During the early design phase, an analysis that identifies conditions that may cause injury or death to personnel and damage or loss to equipment and property shall be performed. Prior to the final safety design review, the design agency shall perform a second systems safety analysis to determine adherence of the design to all required safety standards and criteria, and to ensure avoidance or reduction of identified hazards. Operating and maintenance procedures shall also be reviewed for compliance with all required safety standards and criteria.

**TM 5-691**

(3) The systems safety program shall include procedures to ensure that safety hazards identified by the systems safety analyses are eliminated or reduced to acceptable levels of risk, and that those actions taken are fully documented.

(4) The design agency shall prepare specific safety program documentation. This documentation shall include, but not be limited to, safety analysis reports and the final systems safety report.

d. The design agency shall develop a consolidated systems test program that covers all phases of testing, develops confidence in the system, and provides means for interim and final acceptance of equipment and systems. The design agency shall minimize cost through elimination of testing duplication and by maximizing the collection of data for each test. Successful completion of these tests shall be accomplished prior to final acceptance.

e. The design agency shall develop and implement a standardization program to minimize equipment and component stockage. Redundant systems shall be of the same design.

f. The configuration management (CM) program shall maintain effective control over design from criteria development through design, construction, and installation of the equipment. A government configuration control procedure shall be developed by the design agency for use in the C4ISR utility systems configuration control program.

g. Operations and maintenance (O&M) planning will be done by the design agency and shall identify and recommend essential items of the program during the design phase. A reliability centered maintenance (RCM) program should be implemented to identify single point failures and identify the critical systems. Basic elements of the program are as follows.

(1) As part of the SE database, data requirements shall be identified for preparation of O&M manuals. Systems functional descriptions shall be developed. Requirements shall be developed for data collection, including repair parts list, calibration requirements, special tools and test equipment, repair parts stockage level, and shelf life data. Repair parts list, repair parts stockage level, test equipment, and test frequency shall be provided for the using government agency.

(2) Systems and equipment of high complexity or peculiarity shall be identified, and special training for personnel who operate and maintain such systems and equipment shall be identified.

(3) The design agency shall identify those items critical to accuracy and repeatability, and shall recommend calibration requirements. Unique calibration requirements and procedures shall be provided whenever necessary.

(4) Systems test and checkout requirements to be performed following major maintenance activities shall be developed during design to ensure safe and normal operation of the system.

**2-3. Systems engineering database**

The systems engineering database (SEDB) shall serve all data needs for the system from functional equipment development to final design. The design agency shall develop the formats for data input and output. Cross-references shall be made between required data elements and required deliverable documentation.

#### **2-4. Reliability and availability (R/A)**

The R/A design goal for each of the C4ISR utility systems subsystems shall be 0.999999 (approximately 31 seconds of downtime per year) unless the using government agency determines that a greater frequency of mission outages is acceptable. The C4ISR utility systems design shall be evaluated by use of standard R/A analysis techniques to ascertain if the subsystems and mission goals have been met.

#### **2-5. Life-cycle cost analysis**

A life-cycle cost analysis (LCCA) shall be performed on all viable alternatives to determine the most cost-effective prime mover, auxiliaries, and supporting systems for the generator set. This analysis shall be performed in accordance with the appropriate service regulations. As a minimum, an LCCA shall be performed for the on-site mode of operation.

#### **2-6. Operational control concept**

All functions required to supply power to the C4ISR technical facilities shall be under the control of on-site personnel. At sites with a central power plant, operators shall be stationed in a continuously manned control room (CR). The location of the CR at such sites shall be established by the using government agency during the preparation of the project design criteria documents or during the design. Only a senior CR operator should be permitted to control equipment at equipment locations. The senior operator shall be provided with local-remote selector switches, push buttons, or equivalent and more convenient means of selecting between operation at the equipment or from the remote CR. The CR shall be equipped with all equipment or devices needed to permit operators to control electrically operated breakers; to start up, synchronize, and shut down generating units; and to observe the status or condition of the electrical and mechanical systems. Such equipment or devices include supervisory, telemetering, and data acquisition systems, if required; central instrumentation, monitoring, and control systems; indication and recording devices; and other equipment or devices noted in subsequent design requirements or as required by the project design criteria. All such equipment or devices shall be conveniently arranged in the CR on consoles, cabinets, or panels to facilitate rapid control operations under normal and abnormal operating conditions for all basic modes of operations.

## CHAPTER 3

### DESIGN CONSIDERATIONS FOR OPERATIONS AND MAINTENANCE

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#### 3-1. General design considerations

The design agency's role in the O&M concept is to establish the foundation for stable C4ISR utility systems that shall provide continuous operation incorporating redundancy (dual systems), readiness (standby systems), flexibility (multiple modes of operations), and standardization (parts and equipment). Power plant facilities, systems, and O&M documentation shall be designed to permit rapid startup and repair of equipment under emergency conditions. O&M functions shall be enhanced through the application of these guidelines by the C4ISR utility systems designer.

#### 3-2. Historical records

A recording device shall be included in the design to provide a log of facility performance. This recorder shall accept either analog or digital signals (such as input and output parameters for generators, main switchgear feeders, uninterruptible power supply (UPS) systems, power distribution units, chillers, etc.), convert them to numerical data, scale them to useful values and store them in electronic storage. The signals should be stored at intervals of 15 minutes or other specified preset time intervals. The recorder shall have the capability to record critical signal values more frequently than the preset recording rate (for example, every five seconds) when prompted by a signal from the operator or operating equipment. The recorder shall automatically return to its primary recording when system operation returns to normal. Records shall be maintained on-site for a minimum of five years. A supervisory control and data acquisition (SCADA) system should be incorporated into the design of the systems.

#### 3-3. Maintenance concept

The design outputs prepared by the design agency shall reflect the following maintenance concepts.

- a. The design agency shall develop and implement an equipment standardization program to simplify equipment maintenance.
- b. The design agency shall specify modular designed subassemblies which will permit rapid repair.
- c. The design agency shall specify that manufacturers provide built-in test modules/fault sensors. Selector switches that allow personnel to access and sequentially monitor operating variables within an assembly shall be provided.
- d. The design agency shall specify that a plate with an equipment tag number be attached to the equipment by the construction contractor. The design agency shall specify a method for identifying and numbering wires and cables, for marking cable termination strips, and for uniformly interconnecting equipment of different manufacturers. Corresponding identity codes shall be used for termination strips and wiring. The design agency shall specify that if a manufacturer changes the characteristics of a purchased component for use in a composite item, the true source identity of the originally purchased part will remain intact.

**TM 5-691****3-4. Evaluations**

The following evaluations shall be an integral part of the design process.

- a. Operations evaluations shall consider both user and system requirements.

- (1) The design agency shall evaluate user requirements to determine operating philosophy and the effect that this philosophy will have on system operation, output efficiency, and personnel safety. The design agency shall determine if limits need to be placed on manual control and, if so, shall specify those limits.

- (2) The design agency shall evaluate the system requirements as to the operational effects produced by changing power by switching the source of electrical power and maintenance or repair activities within the facility. The design agency shall identify equipment controls that are used during maintenance activities and provide individual controls so components can be isolated for maintenance without disrupting system operation. The design agency shall specify areas in the control system that should allow automatic adjustments to system equipment to aid the operator when events occur that demand immediate operator intervention.

- b. The design agency shall evaluate user constraints and parameters to ensure maintainability of the C4ISR utility systems.

- c. The design agency shall perform a hazard evaluation to ensure adherence to Occupational Safety and Health Administration (OSHA), National Electrical Code (NEC), and other locally binding safety standards.

**3-5. Operations and maintenance documentation**

The design agency shall perform an O&M analysis to identify the equipment in the C4ISR utility systems that contributes significantly to the maintenance burden of the system and the O&M data required to support maintenance of this equipment by the using government agency. This analysis shall be coordinated with the using government agency to determine maintenance parameters and O&M data that are available to the using government agency.

- a. The design agency shall identify O&M data requirements on an individual basis for all maintenance-significant equipment. Typical data requirements include the following items.

- (1) Minimum spare parts list.
  - (2) Recommended spare parts list.
  - (3) Recommended onsite test equipment.
  - (4) Recommended O&M training.
  - (5) Recommended O&M to be performed by contract.

- b. The design agency shall specify functional areas of the operating system and/or equipment where a technical representative will be furnished by the manufacturer for training, test, checkout, validation, or pre-operational exercises.

c. The design agency shall specify that the construction contractor submit a schedule, listing manufacturer and vendor data that will be furnished for review and approval by the using government agency. O&M data for each equipment item shall be submitted to the using government agency prior to or at the time payment is requested for the equipment. Submission of the final data shall be completed prior to final acceptance of the facility by the using government agency.

### **3-6. Verification**

A verification of O&M procedures and data manual content shall be performed by the using government agency to demonstrate technical accuracy, fulfillment of intent, and applicability to the performance of O&M within the facility. A review of the verification process may necessitate that additional information be obtained from the equipment manufacturer.

a. Verification should begin during the equipment acceptance process and continue as the using government agency applies the instructions, data, and technical manuals to the continuous routines of equipment operation and repair.

b. The design agency shall support the user's verification process by:

(1) Specifying acceptance test procedures which the contractor shall be expected to fulfill during facility acceptance. The format should contain adequate sign-off routines to verify the performance of equipment in accordance with design specifications.

(2) Requiring that, for specially designed equipment that does not fit well into a standard acceptance format, the contractor shall submit an acceptance plan in lieu of the designer-specified acceptance test procedures.

## CHAPTER 4

### CIVIL AND SITE ENGINEERING AND WASTEWATER AND STORM WATER MANAGEMENT

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#### 4-1. General civil, site, and waste management design

These criteria shall be applied in the planning, design and implementation of projects involving site development, sanitary wastewater collection systems and storm water management systems. Their purpose is to provide the minimum requirements for the preparation of site-specific general design criteria and project-specific design criteria during the project planning phase. Many of the departmental organizations have responsibilities for facility planning, design, and construction; therefore, the particular organization may establish and apply more comprehensive criteria to satisfy the particular program mission or operating requirements. The general design criteria need not take precedence over such other criteria, where those criteria meet or exceed the general design requirements.

#### 4-2. Site development

The design agency shall consider the following site development criteria when locating new C4ISR facilities and buildings.

a. A site development plan shall be used to locate new facilities on existing or new sites to assure effective site utilization and to preclude future conflicts between existing and new facilities.

(1) During site selection for new facilities, the following conditions and requirements shall be considered.

- (a) Natural topographic and geologic conditions
- (b) Existing cultural, historic, and archaeological resources
- (c) Endemic plant and animal species
- (d) Health, safety, and environmental protection requirements
- (e) Indoor air quality impacts (e.g., presence of radon in foundation soils, building materials that off-gas irritating chemical vapors, and the need to “bake out” new buildings prior to occupancy)
- (f) Hazardous operations and consequences of potential accidents in adjacent facilities
- (g) Natural hazards including seismic activity, wind, hurricane, tornado, flood, hail, volcanic ash, lightning, and snow
- (h) Wave action within any natural or man-made body of water
- (i) Physical protection requirements

**TM 5-691**

(j) Adequacy of existing or planned support and service facilities, including utilities, roads, and parking areas

(k) Interrelationships between facilities and aesthetic compatibility

(l) Energy conservation requirements

(m) Impact of site selection

(n) Utility maps should be researched and reviewed to verify the location of any buried gas pipes, buried electrical cables, underground supplied water system, sewer systems, etc.

(2) The prior use (e.g., spoil area, buried man-made objects and utilities, ponds, burial grounds, etc.) of the site shall be investigated as part of the location analyses for facility siting. To the extent possible, facility siting shall preclude the use of floodplains or areas subject to flash floods and shall minimize destruction, loss, or degradation of wetlands.

b. New buildings and building additions shall be located in accordance with the site development plan. Open space shall be provided between structures (to accommodate site security, landscaping, and other environmental considerations). Sufficient access shall be provided around building exteriors (to accommodate emergency vehicles, maintenance vehicles, and snow removal equipment). In cold climates, building entrances, stairs, and other pedestrian circulation features should not be placed along the north side of buildings or within shaded areas. During site selection for new buildings, the following conditions and requirements shall be considered.

(1) Architectural and functional compatibility with the environment

(2) Operation and service functional relationships

(3) Natural topographic and geologic conditions

(4) Existing cultural and archeological resources

(5) Historical sites

(6) Abandoned mines or wells and potential for subsidence

(7) Endemic plant and animal species

(8) Availability of existing utility services

(9) Building setback requirements

(10) Availability of existing road systems

(11) Traffic volume

(12) Refuse handling and loading zone requirements

(13) Adequacy for parking, future expansion and other land use requirements



- (14) Health, safety, and environmental protection requirements
- (15) Indoor air quality impacts (e.g., presence of radon in foundation soils, building materials that off-gas irritating chemical vapors, and the need to “bake out” new buildings prior to occupancy)
- (16) Physical protection requirements
- (17) Energy conservation requirements
- (18) Impact of site selection
- (19) Minimum fire separation between buildings
- (20) Previous designation of site for another use

#### **4-3. Sanitary wastewater collection systems**

This section applies to sanitary wastewater collection systems (i.e., lift stations, force mains, collector sewers, and interceptor sewers) and building sewers (five feet beyond the building foundation).

a. System layout. Wastewater collection system layouts shall be as simple and direct as possible. Where feasible, initial planning efforts shall optimize system layouts to facilitate future system expansions, to mitigate conflicts with other utility systems, and to reduce maintenance requirements. Wastewater collection systems shall be included within utility master planning efforts. The following conditions and requirements shall be considered during route selection for new collection systems.

- (1) Future population and development projects
- (2) Anticipated flow rates for fully developed condition
- (3) Physical constraints (e.g., utility corridors, roads and streets, buildings, geologic formations, and topographic features)
- (4) Requirements of other agencies (e.g., state and local)
- (5) Hydraulic design criteria
- (6) Unique conditions (e.g., research and production facility operating schedules)
- (7) Security boundaries and requirements

b. System design considerations. Industrial wastewater and pollutants above Environmental Protection Agency (EPA) minimal concentrations shall be excluded from sanitary wastewater collection systems except where pretreatment systems suitably remove objectionable constituents cost effectively.

- (1) The following factors shall be considered in the design of sanitary sewers.
  - (a) Peak sewage flows from other sources
  - (b) Groundwater infiltration

**TM 5-691**

- (c) Topography and depth of excavation
- (d) Treatment plant location
- (e) Soil conditions
- (f) Pumping requirements
- (g) Maintenance
- (h) Existing sewers
- (i) Existing and future surface improvements
- (j) Controlling service connection elevations

(2) Hydraulic design of wastewater collection systems shall comply with Technical Manuals (TM) 5-814-1, Sanitary and Industrial Wastewater Collection, Gravity Sewers and Appurtenances; TM 5-814-2, Sanitary and Industrial Wastewater Collection-Pumping Stations and Force Mains; and American Society of Civil Engineers (ASCE) 77, Design and Construction of Urban Stormwater Management Systems. All wastewater collection systems shall be designed for gravity flow unless such systems are not economically feasible. Sewage lift stations and force mains shall not be used unless approved by the responsible authority. Feasibility analyses and economic evaluations of lift station and force main costs for construction, operation, and maintenance shall be prepared and submitted to the responsible authority for approval. Sewers and force mains shall be sized to accommodate the estimated daily minimum and maximum discharges for the initial and final years of the design period specified by the responsible facilities engineering group.

(3) In accordance with ASCE 77, velocities in gravity sewers and force mains shall not exceed ten ft/s. Gravity sewers shall be designed for a minimum velocity of two ft/s, and force mains shall be designed for a minimum velocity of 3.5 ft/s.

(4) For preliminary design, domestic water consumption rates shall be used to approximate wastewater flow rates. Where possible, actual flow data from an adjacent service area typical of the service area under consideration shall be used to estimate wastewater flow rates for final design. In the absence of such data, metered water use less the estimated consumptive use (i.e., water withdrawal rate) can be used. Flow rates used in design shall be documented in the calculations.

(5) Sewers and force mains shall have a minimum depth of cover of two feet. Additional cover shall be provided to prevent freezing in cold climates, physical damage, and at roadway crossing in high traffic areas. Sewer or force main trench widths shall be minimized; however, excavations, trenching, and shoring shall comply with 29 CFR 1926, subpart P, Safety and Health Regulations for Construction. Pipe bedding specified by the pipe manufacturer shall be in place prior to installation of sewers and force mains.

(6) Sewers or force mains shall not be routed within 50 feet (75 feet in pervious soils) of any well or reservoir that serves as a potable water supply. The sewer or force main shall be ductile iron pipe in all instances where such horizontal separation cannot be maintained. Where there is a shallow depth to groundwater, special precautions shall be taken to preclude sewer infiltration or exfiltration.

(7) Where feasible, sewers or force mains shall not be routed within ten feet of potable water lines or fire water lines. Where potable water lines must cross sewers or force mains, water lines shall pass two feet above the sewer or force main. Where insufficient cover precludes such vertical separation, the sewer or force main shall be ductile iron pipe or shall be fully encased in concrete for a minimum perpendicular distance of ten feet to each side of the water line crossing. Where feasible, sewer or force main pipe joints shall not be located within three feet of such crossings, unless the joint is encased in concrete.

(8) Where feasible, sewers and force mains shall not be routed under buildings or other permanent structures. Sewers and force mains shall be adjacent and parallel to paved roadways. Sewers and force mains shall not pass beneath paved roadways except at roadway crossings. Where feasible, utility cuts within existing roadway pavement shall be perpendicular to the roadway centerline to minimize trench length. Diagonal roadway cuts shall be avoided where possible. Sewers or force mains that penetrate or pass under a security barrier through an opening of more than 96 in.<sup>2</sup> in area and over six inches in smallest dimension shall provide the same degree of penetration delay as is required for the security barrier.

c. Pipe materials and pipe joints. The selection of sewer and force main pipe material shall be based on wastewater characteristics and soil conditions. Acrylonitrile-butadiene-styrene (ABS) and polyvinyl chloride (PVC) composite sewer piping shall conform to ASTM D2680, Standard Specification for ABS and PVC Composite Sewer Piping. Plastic pipe should be considered where tree root and infiltration are a problem. Ductile iron pipe shall conform to AWWA C151, Ductile-Iron Pipe, Centrifugally Cast, for Water, and shall be used for force main and gravity sewer stream crossings. Ductile iron pipe should also be considered for inverted siphons and for sewers located in parking lots or other high traffic areas. Pipe joints shall have a permanent watertight seal. Maximum infiltration-exfiltration allowances and infiltration-exfiltration test requirements shall be specified within the contract documents.

#### **4-4. Storm water management systems**

The intent of these design criteria for storm water management systems is to promote the conservation of natural resources. This includes preserving the natural beauties of the land, streams and watersheds, hills and vegetation. This also includes protection of public health and safety, including the reduction or elimination of hazards of earth slides, mud flows, rock falls, erosion and siltation. The reduction of the impact of peak water discharges on downstream facilities by minimizing the adverse effects of grading cut and fill operations, surface water runoff, and soil erosion must also be considered.

a. System design considerations. Storm water management systems shall be cost effective and shall provide flood protection commensurate with the value and operational requirements of the facilities to be protected.

(1) The following conditions and requirements shall be considered prior to storm water management system design. In accordance with the Clean Water Act (CWA) as amended by the Water Quality Act (WQA) of 1987, the National Pollutant Discharge Elimination System (NPDES) Permit Regulations require control of point source storm water discharge.

- (a) Local regulations
- (b) Site topography
- (c) Ultimate development within the drainage area

**TM 5-691**

- (d) Requirements for future expansion
- (e) Outfall locations
- (f) Existing drainage systems
- (g) Location of other utilities
- (h) Security boundary and safeguard requirements

(2) Storm water management systems shall be designed for not less than the 25-year, 24-hour storm. The potential effect of larger storms (up to the 100-year, 24-hour storm) shall also be considered. The high intensity, shorter duration storm event (e.g., six-hour storm) is nested within the 24-hour storm event. With this approach, the designer is assured of not overlooking critical events for the small headwater areas of the watershed and has also captured the critical duration for flooding at the mouth of the watershed. With the approval of the responsible authority, lesser design storms may be used where large expenditures for flood protection cannot be economically justified.

(3) Within fully developed watersheds, where the downstream capacity of existing flood control structures has been exceeded, stormwater runoff that results from developed conditions shall be detained on site (ponded) and gradually released. This is so that the capacity of the downstream channels and other control structures are not exceeded and soil erosion is mitigated.

(4) Erosion and storm water control measures shall be designed and provided in accordance with the requirements of these criteria. The erosion control plan shall be detailed on the drawings and the material and requirements included in the specifications. Areas that are being developed or excavated shall apply the following practical guidelines, fitting the various measures to the soil and topography so as to minimize soil erosion and storm water runoff potential.

(5) Provisions shall be made to accommodate increased runoff caused by changed soil and surface conditions during and after development. Erosion control measures, storm water and drainage control measures, detention basins, pipes, structures, and devices for the development shall be planned, designed, constructed, operated, and maintained so that downstream peak discharges after full development are consistent with the pre-developed condition. All storm water improvements shall be designed to sufficiently handle the estimated peak discharge rate from the site. This is so that the post-developed peak discharge rate from a 24-hour duration storm of 25-year frequency shall not exceed the pre-developed peak discharge rate from a 24-hour duration storm of ten-year frequency. Emergency spillways shall be required in the design of detention facilities to permit safe passage of storms in excess of these storm criteria. When warranted by local controlling factors (such as location within a drainage basin, protection of downstream facilities, etc.), and based on sound engineering judgement, storm water detention requirements may be modified or waived. Also, a more stringent storm frequency for the design of such improvements may be required as approved by the responsible authority. In addition, all swales, roads, etc., shall be designed to structurally carry the equivalent 100-year, 24-hour storm to prevent flood damage to nearby buildings and other structures.

(6) Wherever feasible, natural vegetation shall be retained and protected during construction. Where land must be stripped of vegetation during construction, the exposed area shall be limited to the smallest practical size and duration of exposure to the shortest practical time. Temporary soil stabilization measures shall be applied to disturbed areas when and where deemed necessary to minimize soil erosion.

(7) Permanent vegetation; improvements such as streets, storm sewers, or other features capable of carrying storm water runoff in a safe manner; and diversions, grassed waterways, grade stabilization structures, and similar mechanical control measures required for the site shall be installed as early as possible during development of the area.

b. Subsurface drainage systems by means of storm sewers shall be sized to accommodate runoff from the 25-year, 24-hour storm. Subsurface drainage systems shall be sized for a greater storm in locations where there is substantial risk to critical facilities and operations. Sediment transport requirements shall be incorporated within subsurface drainage system designs. Storm sewers shall be designed to maintain adequate scour velocities. New storm sewers shall be sized for open channel flow. The minimum storm sewer size shall be 12 inches. The minimum culvert size shall be 15 inches. For roof drain systems, the minimum pipe size for laterals and collectors shall be four inches.

c. Open-channel storm water conveyance systems shall be sized to accommodate the 25-year, 24-hour design flow with a minimum freeboard. Open-channel drainage systems shall be sized for a greater storm in locations where there is substantial risk to critical facilities and operations. Open-channel storm water conveyance systems shall be designed for minimal maintenance. The potential for scour or deposition within earth-lined channels shall be considered prior to approval by the responsible authority. Preference for earth-lined or hard-lined channels shall be based on comparison of capital, maintenance, and operation costs. Inlets to open-channel storm water conveyance systems shall be placed at locations where erosion potential is minimal.

d. Street drainage in developed areas shall be conveyed within the roadway cross section. Curb inlets shall be used to divert storm flows to surface and subsurface storm water conveyance systems. Curb inlets shall not be located within curb returns or in areas of heavy pedestrian traffic. Pedestrian and cyclist safety shall be considered during selection of storm inlet grates. Curb gaps shall be used where roadside drainage swales exist. In locations where uninterrupted vehicular access is essential to critical operational activities, roadway cross sections shall be designed to convey runoff from the 25-year, 24-hour storm such that one driving lane width (12 feet) is free of flowing or standing water. Storm water management systems shall have sufficient capacity to ensure that runoff from the 100-year, 24-hour design storm will not exceed a depth of 0.87 feet at any point within the street right-of-way or extend more than 0.2 feet above the top of curb in urban streets. Inverted crown roadway cross sections shall not be used unless approved by the responsible authority.

## CHAPTER 5

### STRUCTURAL AND ARCHITECTURAL DESIGN

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#### 5-1. General structural and architectural design

The facility shall provide suitable space for the installation, operation, and maintenance of all utility systems. Structural designs shall utilize material efficiently, provide maximum usable space, minimize the use of special equipment, and be constructed by conventional methods. Consideration shall be given to future uses of the facilities, possibilities of alterations, and maintenance costs. Structural systems shall be compatible with their environment and meet functional needs. Additional design considerations to counter specific threats are covered in appendices to this standard.

#### 5-2. Foundation design

Foundation design shall conform to Technical Manual (TM) 5-818-1, Soils and Geology: Procedures for Foundation Design of Buildings and Other Structures (except Hydraulic Structures).

#### 5-3. Functional layout

Large C4ISR sites will include all of the areas listed below. Smaller sites will only have a subset of the areas described.

- a. The generator room houses the generators and auxiliaries and shall allow sufficient work area around the equipment for normal operation, maintenance, and overhaul. Adequate space shall be provided for engine tear-down and overhead cranes provided for lifting engine/generator components.
- b. An area shall be provided for maintenance and repair of equipment, including special shops for mechanical and electrical maintenance. Areas are required for parts storage, tool storage, and storage of toxic/flammable liquids.
- c. The CR shall house the control consoles, instrument panels, computer systems, and switching and monitoring equipment necessary for central operation of the plant. The operators shall be able to view the generator room equipment from the CR. The operators should also be able to view the distribution switchgear room.
- d. Electrical equipment areas, battery rooms, mechanical/fire protection areas, and other support equipment shall be separated from each other and the other areas in the facilities. Support areas shall be separated by fire walls.
  - (1) A mechanical/chiller room is required for housing heating, ventilating, and air conditioning (HVAC) equipment for the power plant. Fire protection support equipment and air compressor equipment shall be placed in separate rooms.
  - (2) Electrical equipment areas are required to house switchgear and related equipment.
  - (3) A separate battery room is required for large capacity UPS systems utilizing wet-cell batteries.

**TM 5-691**

e. The planning and design phases should incorporate the applicable building and site design standards required by the Unified Facilities Criteria (UFC) and DOD minimum anti-terrorism/force protection (AT/FP) standards for buildings.

**5-4. Exterior walls and roofs**

The exposed exterior surface material and roofing system with insulation shall be cost-effective, based on life-cycle cost studies. Architectural style, including exposed surface materials, shall be compatible with the design and materials of other buildings in the area.

**5-5. Floors and floor finishes**

Floors in the facility shall be constructed of reinforced concrete. Equipment and maintenance areas shall have a dust-proofing sealer on the concrete. A raised access floor shall be provided in the CR. Offices, break room, and CR shall have resilient flooring. Floors in the toilet and locker room shall have an easily cleaned impervious finish. Floors in the battery area shall have an acid-resistant finish.

**5-6. Acoustical treatment**

Noise abatement shall meet the requirements of Department of the Army Pamphlet (DA PAM) 40-501, Hearing Conservation Program. The noise level shall not expose the occupants to sound levels in excess of those shown in MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities; MIL-STD-1474, Noise Limits for Military Material; and DA PAM 40-501. Sound pressure levels within the CR shall not exceed 60 dBa. The facility design and materials shall interrelate and optimize the following factors - arrangement and spacing of the engines, acoustical insulation and design of exhaust and intake systems, and acoustical characteristics of the building construction.

**5-7. Life-safety**

Building design shall conform to the requirements of National Fire Protection Association (NFPA) 101, Life Safety Code.

**5-8. Eye washes and showers**

Eye wash fountains and emergency showers shall be included in the battery and maintenance areas.



## CHAPTER 6

### FIRE PROTECTION SYSTEMS

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#### 6-1. General fire protection system design

All new designs, modifications to existing facilities, and retrofits that have a possible effect on fire safety shall be reviewed by a qualified fire protection engineer. All areas, except as otherwise noted, shall be protected by fire suppression systems with each functional area having a separate zone valve. The sprinkler system(s) shall be hydraulically designed. All areas shall be provided with detection system(s) appropriate to the hazard. All areas shall be provided with manual fire extinguishers appropriate for the hazard. Fire protection systems for Department of Defense (DOD) facilities shall comply with military handbook MIL-HDBK-1008C, Fire Protection for Facilities Engineering, Design, and Construction and NFPA codes, except as modified herein. If the using government agency regulations are more stringent than the NFPA codes, then in all cases the most stringent requirement shall be met.

#### 6-2. Authority having jurisdiction (AHJ)

The term "AHJ" shall mean the component office of responsibility. The AHJ shall have final approval of drawings and interpretation of code relating to the fire protection systems.

#### 6-3. Services and qualifications of fire protection engineer

Fire protection drawings, specifications, and calculations shall be prepared under the supervision of, and be approved by, a licensed and/or degreed fire protection engineer.

#### 6-4. Specifications

The design agency shall prepare and/or utilize the following specifications when installing or modifying fire protection systems.

- a. All installations of new sprinkler systems and all modifications to existing systems shall be accomplished after the preparation of a performance specification. The performance specification shall be prepared to secure the services of a fire protection engineer and a recognized sprinkler seller licensed under the state in which the work is to be performed for the design and installation of the system(s).
- b. Guide specifications which are issued and approved by the DOD components shall be used in the procurement of sprinkler systems for new facilities and processes, as well as modernization, renovation, and repair work on existing facilities.

#### 6-5. General design requirements

Total volume, pressure, and design flow rate of water necessary to provide fire protection for facilities shall be determined by the methods described in the following paragraphs. All sprinkler or other automatic fire suppression system components shall be Underwriters Laboratories (UL) or Factory Mutual approved for the particular application chosen. The type of fire suppression system and agent to be used for the individual facility areas shall be based on guidance in MIL-HDBK-1008 and NFPA 10 and subject to the approval of the site AJH.



**TM 5-691**

a. NFPA 13, Installation of Sprinkler Systems, and MIL-HDBK-1008C shall be used to determine the Occupancy Hazard Classification. Light hazard occupancy rules are prohibited.

b. The design of sprinkler systems shall be in accordance with the requirements of the NFPA 13, 14, Installation of Standpipe and Hose Systems, and 15 (latest revisions), Water Spray Fixed Systems for Fire Protection, and their appendices. All sprinkler systems shall comply with NFPA 13. All supports and hangers shall be in accordance with NFPA 13 and 14. The design of fire protection systems to withstand seismic events shall be in accordance with the criteria developed by the NFPA. Installation of standpipe systems shall comply with NFPA 14. Portable fire extinguishers shall comply with NFPA 10, Portable Fire Extinguishers.

c. New sprinkler systems shall be designed using hydraulic calculations. Calculations shall follow the format of NFPA 13. Additions to existing pipe schedule systems may be designed using the pipe schedule method. NFPA 13 shall be used to determine water supply requirements for hose streams (gpm) and duration (minutes). Density curves presented in NFPA 13 shall be used for calculating sprinkler demand for hydraulically designed systems. For hazard classifications not covered in NFPA 13 and certain other special occupancies or hazards, design density and area of coverage shall be as specified by other more appropriate standards referenced in NFPA 13 or within MIL-HDBK-1008C. For ordinary hazard occupancies and above, hose stream requirements shall be a minimum of 500 gpm regardless of the hose stream demands listed in the above references unless otherwise specified. The maximum design velocity shall be 20 fps. Determination of adequacy of water supply shall be made on the basis of actual flow test data gathered using the methods in NFPA 13.

d. Materials for the construction of sprinkler systems shall be fully specified in the design package or performance specifications. All materials shall be listed in the UL Fire Protection Equipment Directory or in the Factory Mutual Approval Guide. Approval of materials will be based on the manufacturer's published ratings.

e. Automatic sprinkler system and fire protection extinguishing system designs shall be produced on separate drawings and shall never be incorporated in drawings showing other piping systems. Separate drawings shall be produced for each building.

(1) For work to be done by a sprinkler contractor, complete shop drawings must be submitted for approval before proceeding with any work. The drawings shall be to a convenient scale, clearly indicating the essential details including all specialties, concealed spaces, and ventilators. In general the shop drawings shall include a layout of the sprinkler or hose systems, or a combination of both systems, in the designated areas. The fabrication number of all pipelines, locations, test pipe, drain connections, valves, hangers, and other pertinent features shall be shown on the layout. The size, number, type, and temperature ratings of the sprinkler heads shall also be shown on each layout.

(2) As-built drawings of all sprinkler construction shall be provided.

f. Sprinkler systems shall normally be wet pipe in accordance with NFPA 13 for the appropriate occupancy hazard classification for the facility. Hydraulic designs shall be provided for all systems.

g. In unheated areas or other areas subject to freezing temperatures, dry pipe systems shall be provided. Because of the time delays associated with release of the air in the system, water demands for dry pipe systems shall be computed over areas 30 percent greater than for comparable wet pipe systems. Where the unheated area is small it may be cost effective to install an antifreeze system or small dry pipe system supplied from the wet pipe system in the main heated area.

h. For extra hazard areas and specific hard-to-extinguish fuels such as explosives and pyrophoric (spontaneously igniting) metals, a deluge system with open sprinkler heads may be used to wet down the entire protected area simultaneously. Deluge systems shall comply with NFPA 13. If quick response is required, indoor deluge system piping may be primed with water and in unheated areas with antifreeze solution. The nozzles must be provided with blow-off caps for water-filled deluge systems.

i. Sprinkler piping shall be arranged to drain through the main drain valve whenever practical. All trapped sections of pipe, except those supplying a single sprinkler, shall be provided with an auxiliary drain valve complete with nipple and cap or brass plug.

j. The following sprinkler system test connections shall be provided.

(1) A test connection not less than 1 inch in diameter, terminating in a smooth bore corrosion-resistant orifice, giving a flow equivalent to one sprinkler of a type having the smallest orifice installed on the particular system, shall be provided to test each waterflow alarm device for each wet pipe system.

(2) In a dry pipe system a test connection not less than 1 inch in diameter, terminating in a smooth bore corrosion-resistant orifice, to provide a flow equivalent to one sprinkler of a type installed on the particular system, shall be installed on the end of the most distant sprinkler pipe in the upper story. It shall be equipped with a readily accessible 1-inch shutoff valve and plug, at least one of which shall be brass. In lieu of a plug, a nipple and cap shall be acceptable.

k. Sprinkler protection shall be provided at the top and under the bottom landing of each stairway.

l. A gate valve, outside screw-and-yoke type, shall be provided on the supply side of the main sprinkler valve inside the facilities. The gate valve shall be provided in addition to the post indicator valve located in the feed main outside the building.

m. Penetrations through concrete floors and walls shall be made with pipe sleeves. All penetrations shall contain firestopping with a fire rating equal to that of the area being penetrated. Shielded penetrations shall be required for fire protection piping that penetrates shielded areas as addressed in Military Handbook MIL-HDBK-419A, Grounding, Bonding, and Shielding for Electronic Equipment and Facilities.

n. Sprinkler piping shall be labeled. All sprinkler pipes shall be painted red (NFPA 13).

## **6-6. Special protection systems**

Special protection systems may be used to extinguish or control fire in easily ignited, fast-burning substances such as flammable liquids, some gases, and chemicals. They shall also be used to protect ordinary combustibles in certain high-value occupancies especially susceptible to damage. Special protection systems supplement automatic sprinklers as described by NFPA and shall not be used to substitute for them except where water is not available for sprinkler protection. The added expense of the supplementary system shall be supported by documented justification. The selection of a particular special suppression system shall be based on the effectiveness of that system or agent for the type of hazard, and the damage likely to be caused by the extinguishing agent, including cleanup and downtime.

## **6-7. Water supply pressure requirements**

Pressure required for sprinklered facilities shall be the pressure required to meet the total demand and shall be determined by hydraulic calculations. The total demand is the required sum of the domestic demand, sprinkler demand, and hose stream demand.

**TM 5-691****6-8. Quantities of water required**

Requirements for fire protection water storage are based on the assumption that there will be only one fire at a time. The quantity of water required is equal to the product of the fire protection water demand and the required duration. This quantity represents fire protection requirements only, and shall be available at all times. Water supply for domestic, industrial, and other demands shall be added to these requirements to determine the total amount of water that is necessary at a facility. No separate water storage facility is required if the public water system supplying a facility is reliable, provides a minimum of two connections (each providing at least 50 percent of the required capacity), has adequate capacity and pressure to meet requirements, and continuous reserve storage.

- a. The total stored supply for fire protection purposes shall be sufficient to meet the maximum required fire flow demand for the duration specified.
- b. In computing the fire protection storage requirement, a reduction in storage capacity is acceptable if an adequate replenishment source is available. Factors that must be evaluated include the reliability of the makeup facility, its sustained flow capacity, its method of operation (automatic or manual), and flow limitations imposed by the capacity of treatment operations.
- c. The water storage shall be self-replenishing. It shall reach required volume during normal consumption within 48 hours, and within 24 hours curtailing normal consumption.
- d. Water demands for sprinklered facilities shall be in accordance with military handbook MIL-HDBK-1008C, table 3, "Water demands for sprinklered facilities," based on the required occupancy classification.

**6-9. Sources of water supply**

Primary and secondary water supplies shall be obtained from the sources described below.

- a. Primary water supplies shall consist of one or a combination of the following.
  - (1) Two connections to a public water system (one connection is ample for a small activity or facility)
  - (2) Elevated tanks or reservoirs
  - (3) Multiple pumps with adequate suction supply
- b. Where public water supply is inadequate or unreliable, a secondary supply is required. Secondary supply shall be by gravity tank, pressure tank, booster pumps taking suction from adequate capacity main(s), or fire pumps taking suction from adequate source(s).

**6-10. Water distribution and storage**

Fire water distribution and storage systems will be based on the following guidance.

- a. Wherever practical, dedicated fire water storage and distribution systems shall be used. If a dedicated fire water supply system cannot be provided, the fire protection water supply shall assure availability regardless of simultaneous process and domestic water usage.

- b. Where automatic sprinkler systems or standpipes are fed from a potable water system, approved check valves shall be installed in sprinkler lead-ins to preclude the introduction of pollutants from systems or recirculation of stagnant water that would contaminate the domestic water system.
- c. Underground fire water mains or combined fire and domestic water mains, including valves, hydrants, and fittings, shall be installed, flushed, sterilized, and tested in accordance with NFPA 24, Private Fire Service Mains. Water storage tanks shall comply with NFPA 22, Water Tanks for Private Fire Protection. Fire pumps shall comply with NFPA 20, Standard for the Installation of Stationary Fire Pumps for Fire Protection. Water storage shall be sufficient to meet the density, pressure, and duration requirements of NFPA 13.
- d. Whenever feasible, all water distribution systems shall be of the looped grid type providing two-way flow with sectional valving arranged to provide alternate water flow paths to any point in the system. Dead-end mains shall be avoided. Fire mains (except those supplying a single hydrant or extensions of existing smaller mains) shall be at least eight inches. Mains shall be sized to supply the largest fire demand plus the largest domestic and process demand with consideration for residual sprinkler system pressure requirements.
- e. Sprinkler supply lead-ins should be at least six inches, except lead-ins of four inches may be used for very small sprinkler systems when substantiated by hydraulic calculations. In no case shall the lead-in be smaller than the sprinkler riser.
- f. Where combined fire and domestic process water systems are used, the supplies to each building shall be arranged and valved so that the domestic and process systems can be shut down without shutting off the fire system supply.
- g. Sprinkler risers should be located at an exterior wall of a dedicated sprinkler riser room. Sprinkler supply lead-ins should run under buildings the minimum distance possible.
- h. Outside control valves that can be locked open shall be provided on each supply lead-in located if possible a minimum distance of 40 feet from the building. Post indicator valves (PIVs) should be used where possible. If site conditions preclude the use of PIVs, such as where they would be subject to mechanical damage and cannot be properly guarded, outside screw and yoke valves in pits may be used.
- i. Key-operated buried valves shall not be used for sprinkler control valves. In no case shall there be more than one valve controlling a sprinkler supply lead-in.
- j. All lead-ins shall be connected with the sprinkler system at the base of the riser. Alarm valves shall be located as close as practical to the building entry point. Hydrants shall be provided so that hose lays from hydrants to all exterior portions of a protected building are no more than 300 feet. Hydrants shall not be closer to buildings than 50 feet. For new construction, at least one hydrant shall be located within 150 feet of fire department connections. Hydrants shall comply with requirements of MIL-HDBK-1008C.
- k. Design water mains supplying fire protection systems and fire hydrants to meet further requirements of NFPA 24.

### **6-11. Fire pumps**

Pumps shall be provided to boost pressure for municipal water systems if needed, and to provide pressure to the sprinkler system when supplied from a secondary water source. Fire pumps, drivers, and controllers shall meet the requirements of NFPA 20.

**TM 5-691**

- a. A fire pump may be either a horizontal or vertical shaft centrifugal pump or a vertical shaft turbine pump, whichever is most economical and appropriate for the intended use. A horizontal centrifugal pump in either the horizontal or vertical position shall not be used where suction lift is required. A vertical shaft turbine pump shall be used for suction lift.
- b. Fire pumps shall be arranged to start automatically except that they shall be arranged for manual starting when other available water supply sources are capable of providing demands for automatic sprinkler systems simultaneously with domestic and industrial demands. The fire pump shall be capable of being remotely operated from the CR.
- c. Fire pumps shall be fed from a reliable single power source or from two independent sources in accordance with NFPA 20 during normal operations. Upon a loss of the commercial electrical power, fire pumps shall be fed from the emergency generator circuit. Spark ignited internal combustion engines shall not be used to drive fire pumps. Diesel engine driven fire pumps in accordance with NFPA 20 will be acceptable.
- d. The fire pumps shall be provided with an automatic operating water level controller. The controller shall operate using water pressure control or fire protection equipment control.

**6-12. Mission areas**

These areas include major automated data processing (ADP) areas, communications centers, command and control system areas, computer areas, and other mission critical areas. Unless otherwise specified, MIL-HDBK-1008C and NFPA 75, Electronic Computer/Data Processing Equipment, shall be followed in the design and construction of computer and electronics mission areas. Computer areas shall be separated from other occupancies within the building by fire-resistant rated construction.

- a. An automatic sprinkler system shall be provided to protect mission areas. Sprinkler systems protecting mission areas shall be valved separately from other sprinkler systems. Halon<sup>®</sup> 1301 systems shall not be used. It is assumed that strategically important spaces are staffed 24 hours a day for 365 days a year. Therefore, adequate extinguishers appropriate to the hazard should be a sufficient replacement for the total flooding system. However, extinguisher protection cannot be considered as a substitute for an automatic sprinkler system. Mission-essential electronic equipment shall be protected with wet pipe sprinkler systems. Preaction systems shall not be used.
- b. Smoke detectors shall be provided for all electronic equipment areas. Automatic detection systems shall be installed at the ceiling level and below the raised floor spaces. Automatic detection should also be provided above ceilings and in attics where equipment or wiring is installed in order to alert facility personnel to the presence of smoke and/or fire before it enters the electronic equipment areas. Smoke detectors shall be the photoelectric type. Ionization detectors may be used if they are cross-zoned with photoelectric detectors and are rated for high airflow. In cable trays, line-type heat detectors shall be used. The detection system shall be cross-zoned. Automatic equipment power shutdown, activated by sprinkler water flow or two smoke detectors, shall be provided via the fire alarm control panel. Automatic shutdown of the computer room air-conditioning units by the fire alarm control panel shall also be provided.
- c. Under floor spaces of less than 5000 cubic feet in volume do not require a fire extinguishing system. Under floor spaces shall not be subdivided to reduce total volume. Where the air space below a raised floor or above a suspended ceiling is used to recirculate computer room/computer area

environmental air, the wiring shall conform to Article 645 of NFPA 70, NEC. A structural floor where a computer system is located, or that supports a raised floor installation, shall incorporate provisions for drainage from domestic water leakage, sprinkler operation, coolant leakage, or fire fighting operations. Structural supporting members and decking for raised floors shall be noncombustible. Access sections or panels shall be provided in raised floors so that all the space beneath is accessible.

d. Listed portable extinguishers suitable for use on electronic equipment shall be provided. Listed extinguishers with a minimum rating of 2-A shall be provided for use on fires in ordinary combustible materials, such as paper and plastics. A sign shall be located adjacent to each portable extinguisher and shall plainly indicate the type of fire for which it is intended. Where inside hose is provided, the hose shall be 1-1/2 inch rubber-lined hose with shutoff and combination solid-stream and water-spray nozzles. It shall be installed and maintained in accordance with NFPA 14.

e. A means shall be provided to disconnect power to all electronic equipment in the mission areas. There shall also be a similar means to disconnect the power to all dedicated HVAC systems serving the areas and to cause all required fire/smoke dampers to close. The control for these disconnecting means shall be grouped and identified and shall be readily accessible at the principal exit doors. A single means (i.e., a panic button) to control both the electronic equipment and HVAC systems shall be permitted. A similar disconnecting means shall also be required for UPS systems installed within the mission areas. This disconnecting means shall also disconnect the battery from its loads.

### **6-13. Mission administration**

The administrative spaces in the mission area may be connected to the same sprinkler system as the mission spaces. The entire mission administration area shall be protected with an automatic sprinkler system. The requirements of NFPA 101, Life Safety Code, shall be met unless otherwise specified. Specific requirements for mission administration area(s) include the following.

- a. Office and dayroom spaces shall be equipped with smoke detectors.
- b. Range-top cooking surfaces located in common areas (i.e., not in individual units) shall be protected with an approved range-top extinguishing system. Such systems shall be connected to the building fire alarm system to sound a general building fire alarm. A range-top extinguishing system is not required when the building is protected by an approved automatic sprinkler system.
- c. Hard-wired smoke detectors in accordance with NFPA 72, National Fire Alarm Code, shall be provided in sleeping areas. A hard-wired smoke detector shall be provided for each sleeping area or room regardless of occupancy or the presence of other detection or protection systems in the building. When activated, the affected detector shall generate an audible signal in the room. Detectors which use a battery as the primary power source are not permitted. Sleeping areas shall have Class A interior finishes.

### **6-14. Generator set area**

Installation, maintenance, operation, and testing requirements as they pertain to the performance of emergency power supply systems shall comply with NFPA 110, Emergency and Standby Power Systems. Installation of prime movers and accessories shall comply with NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines, except as modified by NFPA 110. In general, electrical installations shall conform to Article 700 of NFPA 70.



**TM 5-691**

a. Emergency generator sets shall be located in a separate room that is separated from the remainder of the building by fire separations having a minimum 2-hour fire rating. Or, generator sets shall be located in a separate generator building capable of preventing the entrance of snow or rain, resisting maximum wind velocity required by the local building code, and preventing flood damage, sewer water backup, and similar disasters. Consideration shall be given to the location of the emergency generators to minimize the possibility of damage caused by vandalism, sabotage, and other similar occurrences. Generators shall be installed in a location that will permit ready accessibility and adequate working space around the unit.

b. A separately zoned system shall be provided for each prime mover above the finished floor. The area below the finished floor under each unit, including all sumps, trenches, and drainage pits shall be provided with a separately zoned automatic sprinkler system. Containment barriers shall be installed in sump/trench areas between the generators to prevent an oil fire from spreading the length of the power plant. Electrical equipment shall be protected with hoods or shields of noncombustible materials or housed in National Electrical Manufacturers Association (NEMA) 4X enclosures designed to be wetted without adverse effects.

c. Each emergency generator shall be provided with approved fire extinguishers of appropriate size, type, and number as specified in NFPA 10.

d. Emergency generator rooms or separate generator buildings shall be equipped with fire detection systems in accordance with NFPA 72.

e. Emergency generators shall be adequately protected from damage due to lightning.

f. Openings in the emergency generator room that open to other sections of the building shall be provided with automatic or self-closing fire doors or dampers to confine a fire to the generator room.

**6-15. Switchgear and uninterruptible power supply areas**

Installation, maintenance, operation, and testing requirements as they pertain to the performance of the stored emergency power supply systems (i.e., UPS) shall comply with NFPA 111, Stored Electrical Emergency and Standby Power Systems. All areas of the switchgear and UPS areas shall be fire-rated, including all penetrations. These areas shall be protected by photoelectric smoke detectors and an automatic sprinkler system. Total flooding Halon<sup>®</sup> 1301 systems shall not be used. The consideration of halon substitutes (such as FE-200) shall be subject to the approval of the site AHJ. The UPS shall be permitted to be located in switchgear or other electrical service room, provided that the manufacturer's environmental specification is met. The rooms or buildings housing the UPS shall be located to minimize the possibility of damage from flooding, including flooding resulting from fire fighting, sewer water backup, and similar disasters or occurrences. The UPS shall be installed in a location that allows ready accessibility and adequate working space for the inspection, repair, maintenance, cleaning, or replacement of the unit.

**6-16. Battery room**

The battery room shall be of fire-rated construction. A fire detection system and an automatic sprinkler system shall be provided. An automatic ventilation system shall be provided that keeps the battery room hydrogen (H<sub>2</sub>) concentration below 2.0 percent by volume at all times. The ventilation volume shall be referred to chapter 7, paragraph 7-15, Uninterruptible power system battery room ventilation. A trouble alarm shall be transmitted to the central receiving station if the concentration of H<sub>2</sub> exceeds the control limit. Portable fire extinguishers appropriate to the hazards shall be located in and adjacent to the battery

room. Rooms or buildings housing the stored emergency power supply system (i.e., UPS, central battery system, etc.) shall be located to minimize the possibility of damage from flooding, including flooding resulting from fire fighting, etc.

#### **6-17. Control Room (CR)**

The CR shall be provided with photoelectric smoke detectors, a smoke evacuation system, and an automatic sprinkler system. Fire extinguishers appropriate to the hazards shall be located in and adjacent to the CR.

#### **6-18. Data and power cabling areas**

The following guidance shall be used to establish fire protection requirements in areas used to route data and power cables.

- a. Power cables installed in the ceiling plenum or below raised floor shall meet the requirements of NFPA 70, except that use of nonmetallic conduit shall not be permitted. Data and other communication cables installed in ceiling spaces and under raised floors shall be plenum rated or installed in conduit in accordance with NFPA 70.
- b. Different classes of cables, such as medium-voltage, low-voltage, and instrument cables shall be installed in cable trays or raceways specifically dedicated to each class. Where cable trays are arranged in tiers, the cables shall, whenever possible, be installed in tiers in order of fault energy, with the highest fault energy cables in the upper trays and instrumentation cables in the lower trays. Detection in the cable trays shall consist of line-type wire heat detectors.

#### **6-19. Fuel storage area**

Petroleum fuel facilities shall comply with military handbook, MIL-HDBK-1022, Petroleum Fuel Facilities, NFPA 30, Flammable and Combustible Liquids Code, and NFPA 37.

- a. For aboveground storage tanks provide fire protection water mains, hydrants, valves, pumps, and application devices to permit control of brush and grass fires and cooling of storage tanks in the event of a fire exposure. Provide a minimum of two hydrants. Locate hydrants and valves outside of diked areas. Locate hydrants so that protection exposures can be reached through hose runs not exceeding 300 feet (90 m).
- m). Comply with all requirement of MIL-HDBK-1008C for water supply.
- b. Aboveground vertical tanks storing Class II mission critical fuels (i.e., JP-5, JP-8, and diesel fuel used for shipboard fueling) shall be equipped with internal honeycomb floating pans constructed of aluminum. Only aluminum pans providing closed cells and full fuel contact will be permitted in new construction. Foam fire extinguishing systems are not required where internal honeycomb floating pans are installed. Tanks containing other Class II liquids do not require internal honeycomb pans or foam extinguishing systems.
- c. The extent of fire prevention and control provided for the tank storage facility shall be determined by an engineering evaluation of the operation, followed by the application of sound fire protection and process engineering principles.
- d. A venting system appropriate to the class of flammable liquid being stored shall be provided as specified in NFPA 30.



**TM 5-691**

e. If bulk storage is inside the facility, a three-hour separation shall be provided between the storage area and the rest of the facility, and a Class A self-closing fire door shall be installed on each opening into the storage area. Overflow protection shall be provided on storage tanks inside of the facility.

f. The day tanks within the facility shall be protected with the appropriate type of extinguishers. No automatic suppression system is needed near the day tanks since the facility will have an automatic sprinkler system.

**6-20. Loading/unloading areas**

Unless a loading/unloading area is used for storage of supplies, no special provisions except appropriate fire extinguishers should be provided. If the loading/unloading area is used for a storage area, then the requirements of NFPA 230, Fire Protection of Storage, shall be met.

**6-21. Entry control points**

The guard house at an entry control point shall have provisions for automatic fire detection. A signal shall be sent to the central alarm receiving station indicating alarm or trouble. Appropriate fire extinguishers shall be provided.

**6-22. Transmit/receive stations**

All transmit/receive stations and antenna arrays shall have provisions for fire detection. A signal indicating alarm or trouble shall be sent to the central alarm receiving station. Appropriate fire extinguishers shall be provided and located adjacent to the station.

**6-23. Transformer vault/room**

The design agency shall consider the following criteria when establishing the fire protection requirements for transformer installations.

a. Oil-insulated transformers installed indoors shall be located in fire resistive vaults except for indoor transformer installations exempt by NFPA 70. Fire protection for oil-insulated transformers in fire-resistive vaults shall comply with table 2 of MIL-HDBK-1008C. Requirements apply to single-phase or polyphase lighting or power transformers.

b. Transformers insulated with less flammable liquids (fire point not less than 572°F [300°C]), as defined by ASTM D92, Standards Test Method for Flash and Fire Points by Cleveland Open Cup, shall be permitted to be installed without a vault in buildings of Types I and II construction. This applies to areas in which no combustible materials are stored, where there is a liquid confinement area, and where the installation complies with restrictions provided for in the listing of the liquid. Such indoor installations not meeting the requirements of the liquid listing, or installed in other than Types I or II buildings, or in areas where combustible materials are stored shall either be provided with an automatic fire suppression system and a liquid containment area, or installed in an approved vault. Transformers installed indoors and rated over 35,000 volts shall be installed in a vault.

c. Dry type transformers shall be installed and located in accordance with NFPA 70.

**6-24. Generator sump**

The area below the finished floor under each generator unit, including all sumps, trenches, and drainage pits shall be provided with a separately zoned automatic sprinkler system.

**6-25. Cooling towers**

Fire protection for field erected water-cooling towers of combustible construction or those in which the fill is of combustible material shall comply with NFPA 214, Water Cooling Towers.

## CHAPTER 7

### HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS

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#### 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.

**TM 5-691**

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 C4ISR 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.

## TM 5-691

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.

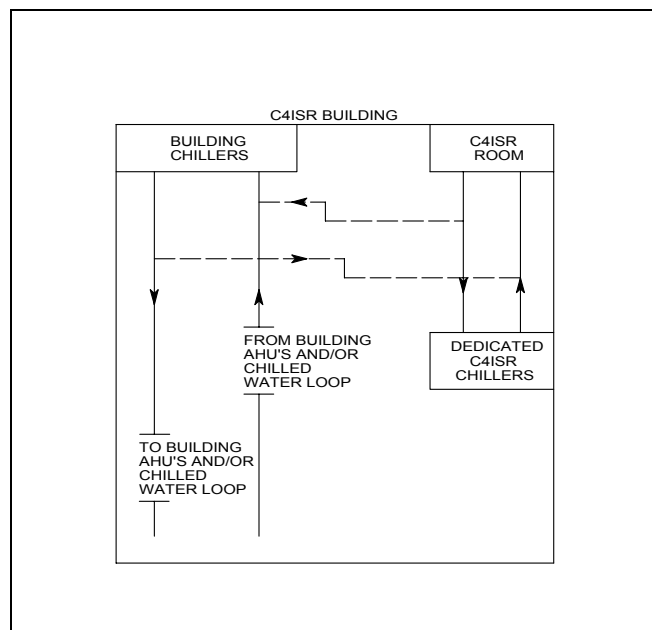


Figure 7-1. Dedicated C4ISR building

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

TM 5-691

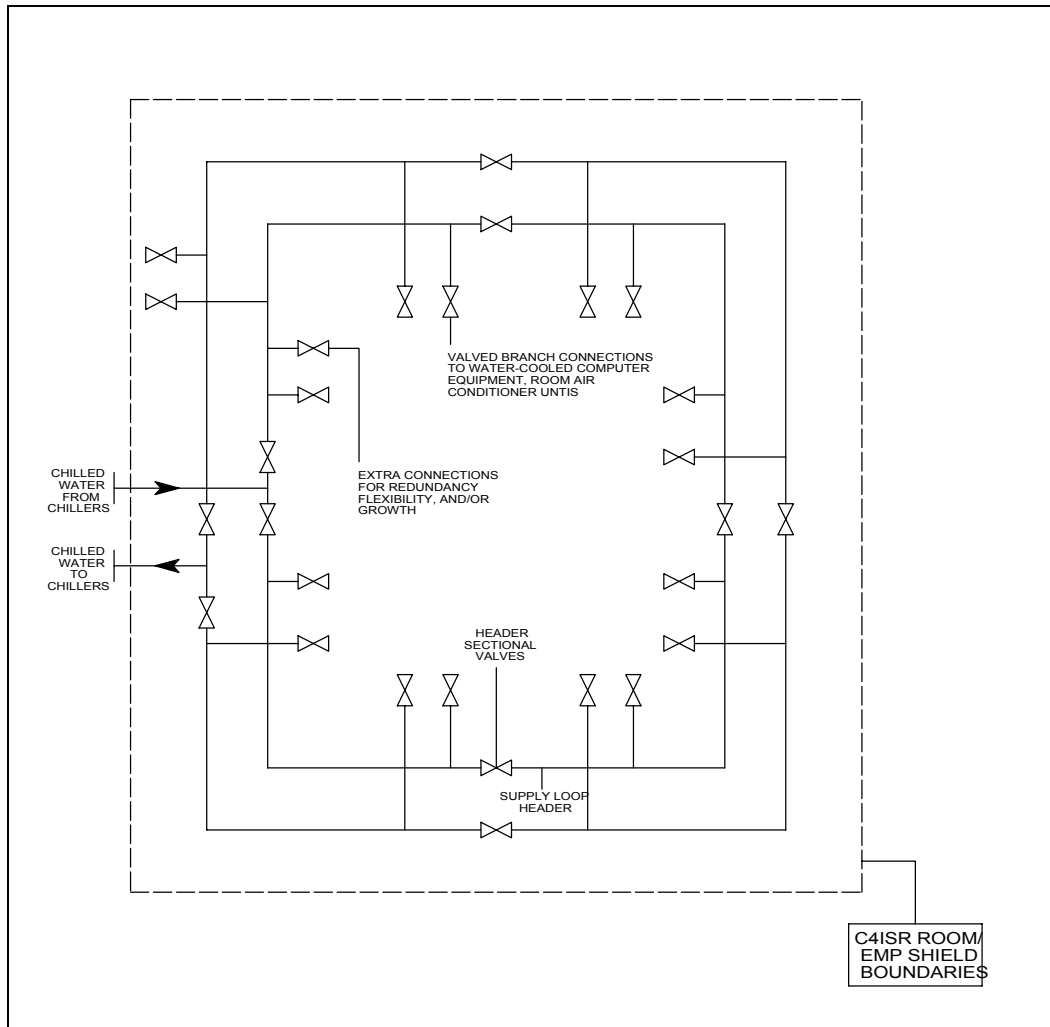


Figure 7-2. Interior C4ISR room piping

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.



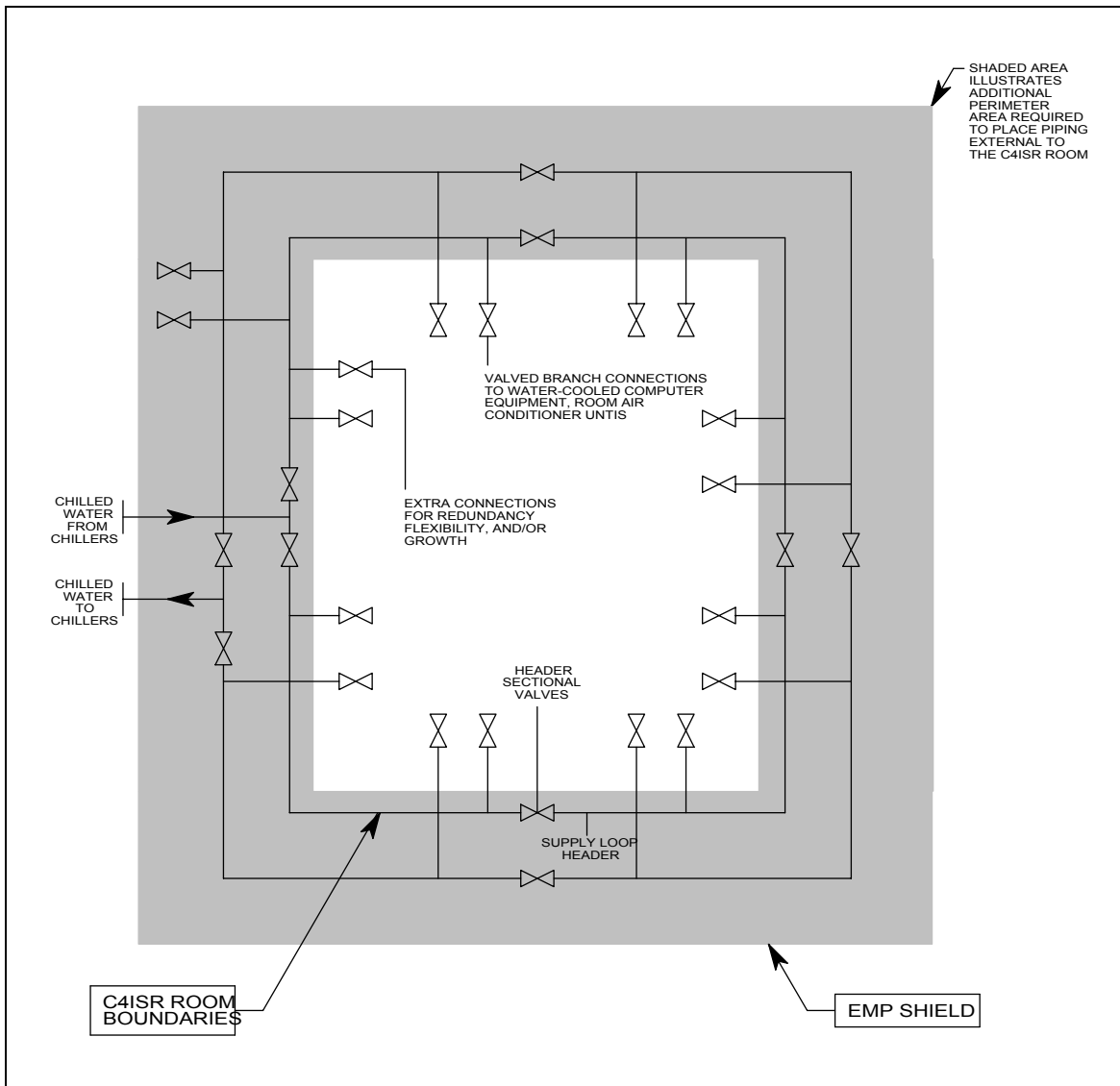


Figure 7-3. Perimeter C4ISR room piping

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.

TM 5-691

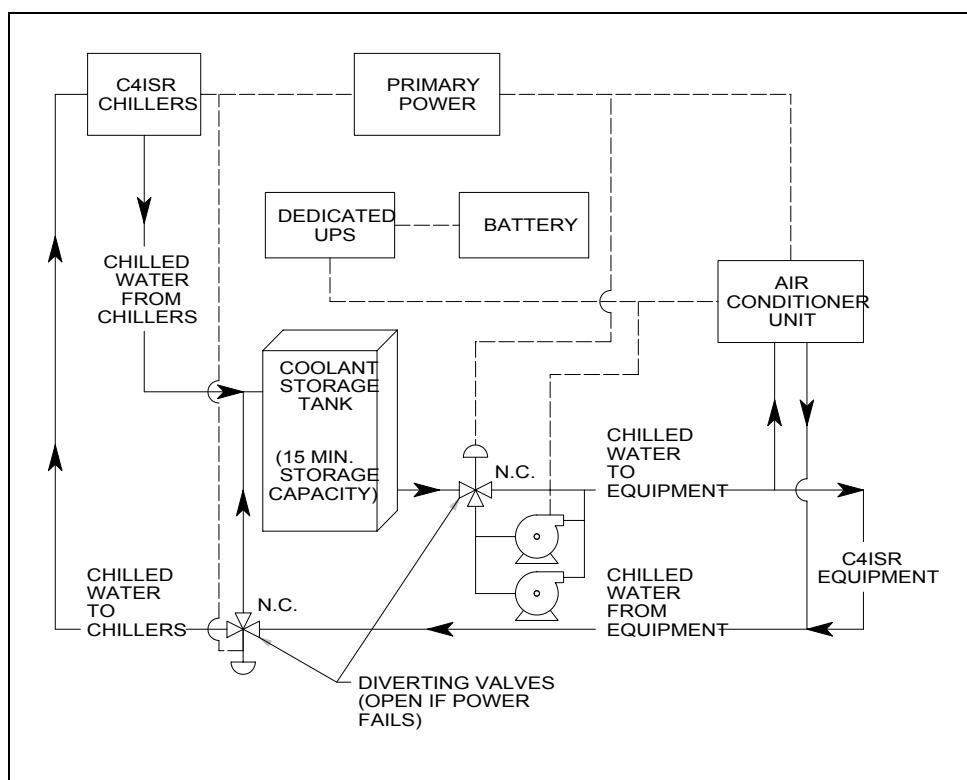


Figure 7-4. System for 15 minute backup cooling capacity

### 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

**TM 5-691**

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 is  $26.7^{\circ}\text{C}$  ( $80^{\circ}\text{F}$ ) 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

**TM 5-691**

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°F to 104°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.



**TM 5-691**

b. Size the battery room ventilation system to prevent hydrogen concentration in the room from exceeding 2 percent by volume. The hydrogen (H<sub>2</sub>) 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:

$$Q = 0.054 \times I \times N \text{ (Reference: TM 5-810-1, Paragraph 4-8)}$$

Where:

Q = Required ventilation rate in ft<sup>3</sup>/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°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°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.

**TM 5-691**

- 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<sub>2</sub> 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.

**TM 5-691**

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 is 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.

## CHAPTER 8

### PIPING SYSTEMS

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#### 8-1. General piping systems design

Policies, criteria, procedures, and responsibilities for operation, maintenance, repair, and construction of facilities and systems for the efficient and economical management of piping utility services shall be in accordance with AR 420-49, Utility Services. Figure 8-1 identifies commonly used symbols and abbreviations for the piping and instrumentation diagrams presented in this chapter.

- a. Potable water will be supplied in accordance with the Safe Drinking Water Act (SDWA) of 1974 as amended in 19 June 1986 (PL 99-339) and in October 1988 by the Lead Contamination Control Act (PL 100-572) (42 U.S.C. 300f, et seq.) and all applicable state and local regulations. Installations that are Outside Continental United States (OCONUS) and classified as suppliers of water will comply with the standards in the National Primary Drinking Water Regulation and final governing standards issued by the Department of Defense (DOD) Executive Agent for the host nation concerned. The theater surgeon may approve OCONUS requests for deviation from the Continental United States (CONUS) drinking water standards.
- b. Treatment of wastewater and non-point source (NPS) pollution control and abatement will comply with the applicable parts of the CWA, as amended (33 U.S.C. 1251, et seq.), AR 200-1, Environmental Protection and Enhancement, and AR 420-79, Natural Resources; Land, Forrest, and Wildlife Management. Measures for NPS pollution control will be included in all construction, installation operations, and land management plans and activities.
- c. Consider possible future expansion when designing fluid systems. Any expansion plans for the systems or facilities shall be considered. In general, if expansions are planned, utilities should be extended to a point where connection can be made without damage or disruption to existing facilities.
- d. Piping for areas planned to accommodate the physically handicapped shall be designed in accordance with the Code of Federal Regulations (CFR), 28 CFR 36, Americans with Disabilities Act (ADA).
- e. All piping systems shall have the capability of being remotely controlled from the control room.
- f. Upon a loss of normal electrical power, piping systems serving mission critical areas or systems shall be powered from the emergency generators. Piping equipment and systems whose loss of power would impact the facility mission (i.e., controls) will be operated from the UPS system until the facility generators can restore power.

#### 8-2. Piping systems reliability and survivability

Piping systems installed in CommandC4ISR facilities shall meet the following reliability and survivability goals.

- a. In mission critical facility applications, mechanical components, such as air compressor systems 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

## TM 5-691








AC	AIR COMPRESSOR	PRV	PRESSURE REGULATING VALVE
AD	AIR DRYER	PS	PRESSURE SWITCH
CV	CHECK VALVE	PT	PRESSURE TRANSMITTER
CWT	COOLING TOWER	RV	RELIEF VALVE
DG	DIESEL GENERATOR	ST	STRAINER
DP	DIFFERENTIAL PRESSURE	T	TEMPERATURE
DT	DAY TANK	TA	TEMPERATURE ALARM
F	FILTER	TI	TEMPERATURE INDICATOR
FCV	FLOW CONTROL VALVE	TK	TANK
FE	FLOW ELEMENT	TS	TEMPERATURE SWITCH
FI	FLOW INDICATOR		INTERLOCK
FR	FLOW RECORDER		CHECK VALVE
FS	FILTER SEPARATOR		PLUG VALVE
FT	FLOW TRANSMITTER		RELIEF VALVE
G	GENERATOR		SHUTOFF VALVE
GV	GATE VALVE		SOLENOID VALVE OPERATOR
HC	HAND CONTROL		STRAINER
L	LEVEL GAUGE		
LA	LEVEL ALARM		
LI	LEVEL INDICATOR		
LT	LEVEL TRANSMITTER		
M	METER		
MT	MAIN TANK		
P	PUMP		
PA	PRESSURE ALARM		
PGV	PLUG VALVE		
PI	PRESSURE INDICATOR		

Figure 8-1. Piping and instrumentation diagram legend

mission, (2) equipment reliability, and (3) equipment cost. The AHJ 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. Piping systems 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 piping equipment to evaluate the magnitude of motion and acceleration established at the mounting points for each piece of 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 piping systems. For example, double suction pumps are more likely to withstand shock forces generated by ground motion with the impeller supported on both sides. Conversely, pumps with overhung impellers should not be used in C4ISR installations unless they are mounted on shock isolated platforms.

### 8-3. Specifications

Guide specifications which are issued and approved by the DOD components shall be used in the procurement of piping systems, HVAC systems, and mechanical systems for new facilities and processes, as well as modernization, renovation, and repair work on existing facilities.



#### 8-4. Cooling water systems

When cooling water is required, it shall be derived from cooling towers, radiators, heat exchangers, wells, or natural water sources and at least one redundant feed source shall be provided. The cooling source reliability and availability, rather than economics shall determine the system to be used. The facilities tactical operating scenario will determine the cooling water system configuration. Design cooling water systems to meet the requirements of ANSI B31.3, Code for Pressure Piping, Chemical Plant, and Petroleum Refinery Piping, for ordinary fluids.

a. A means will be provided for transferring the waste heat from the facilities cooling equipment either to the atmosphere, via cooling towers, radiators, heat exchangers etc., or to a hardened heat sink as directed by the commander or the DPW. The vulnerability to attack surface cooling water sources such as a river, pond, or shallow aquifer may require a hardened facility to include cooling media storage that is available throughout the attack period. Design guidance for hardened facility heat sinks shall be in accordance with TM 5-855-4, Heating Ventilating, and Air Conditioning of Hardened Installations.

b. The cooling tower circulating water systems for C4ISR facilities will generally be of a closed-loop design utilizing cooling towers, storage tanks, basins, pumps, filters, heat exchangers, and water treatment facilities. The cooling towers will be surface mounted or protected below grade if required to escape a blast wave. The exterior cooling water shall be protected from freezing during periods of cold weather. Figure 8-2 shows a typical cooling water flow system for diesel generators using heat exchanger cooling.

c. Liquid-cooled diesel generators shall be arranged for closed-loop cooling and shall consist of one of the following: a unit-mounted radiator and fan; a remote radiator cooling system; or a heat exchanger (liquid-to-liquid) cooling system. Cooling systems shall prevent overheating of prime movers under conditions of highest anticipated ambient temperature at the install elevation when fully loaded. A full load on-site test shall not result in activation of a high temperature alarm or high temperature shutdown. The generator engines shall be equipped with automatic high temperature protection and shutdown. Power for fans and pumps on remote radiators and heat exchanger cooling systems shall be supplied from the diesel generators upon loss of commercial power. On emergency generator cooling systems requiring intermittent or continuous waterflow, pressure, or both, a utility or city water supply service shall not be used as the cooling source. It shall be permitted to use utility or city water for filling or makeup water if the source is reliable and is approved by the DPW.

d. A finned-coil heat exchanger (i.e., radiator) exposed directly to the ambient air may be used aboveground or in a buried chamber to dissipate heat generated by the diesel generator prime movers. An underground radiator that utilizes auxiliary fans to draw (or force) cooling air from the outside through the coil and exhaust the rejected heat to the outside offers a greater degree of protection against the elements (dust or sandstorms) and weapon effects but requires more fan horse-power for air movement. Blast closure devices, debris shields, and dirt traps in the supply and exhaust ducts will increase the level of protection. Generator vaults will have provisions to wash down the radiators and pump out material deposited on the coil surfaces.

e. Cooling towers will generally be cylindrical and constructed of steel or reinforced concrete to resist severe shock loading on aboveground tower structure, including all internals of the tower. Towers with the potential for exposure to direct thermal radiation will have critical parts of the system shielded from this effect. Where cooling towers are required to operate in extreme winter conditions, provision will be made to prevent freezing and ice buildup on the tower. Cooling tower makeup water used during normal operation will be from the domestic water supply or from wells located on the site. Consideration will be given to using hardened storage tanks or hardened wells to provide cooling tower makeup if required for the post-attack period. All pumps installed in the cooling tower circulating water system will be inherently



## TM 5-691

capable of withstanding ground shock or will be dynamically mounted to reduce the shock to an acceptable level. The operation of cooling towers during extreme hot temperatures is greatly impeded by blocked air flow (shrubs, barriers) and reduced effectiveness with scaling and corrosive inhibitors due to water evaporation. Outdoor cooling pipes in extreme cold conditions can be protected by wrapping pipes and installing heat wrap resistance cables. Heaters should also be installed in cooling tower pans to reduce freezing.

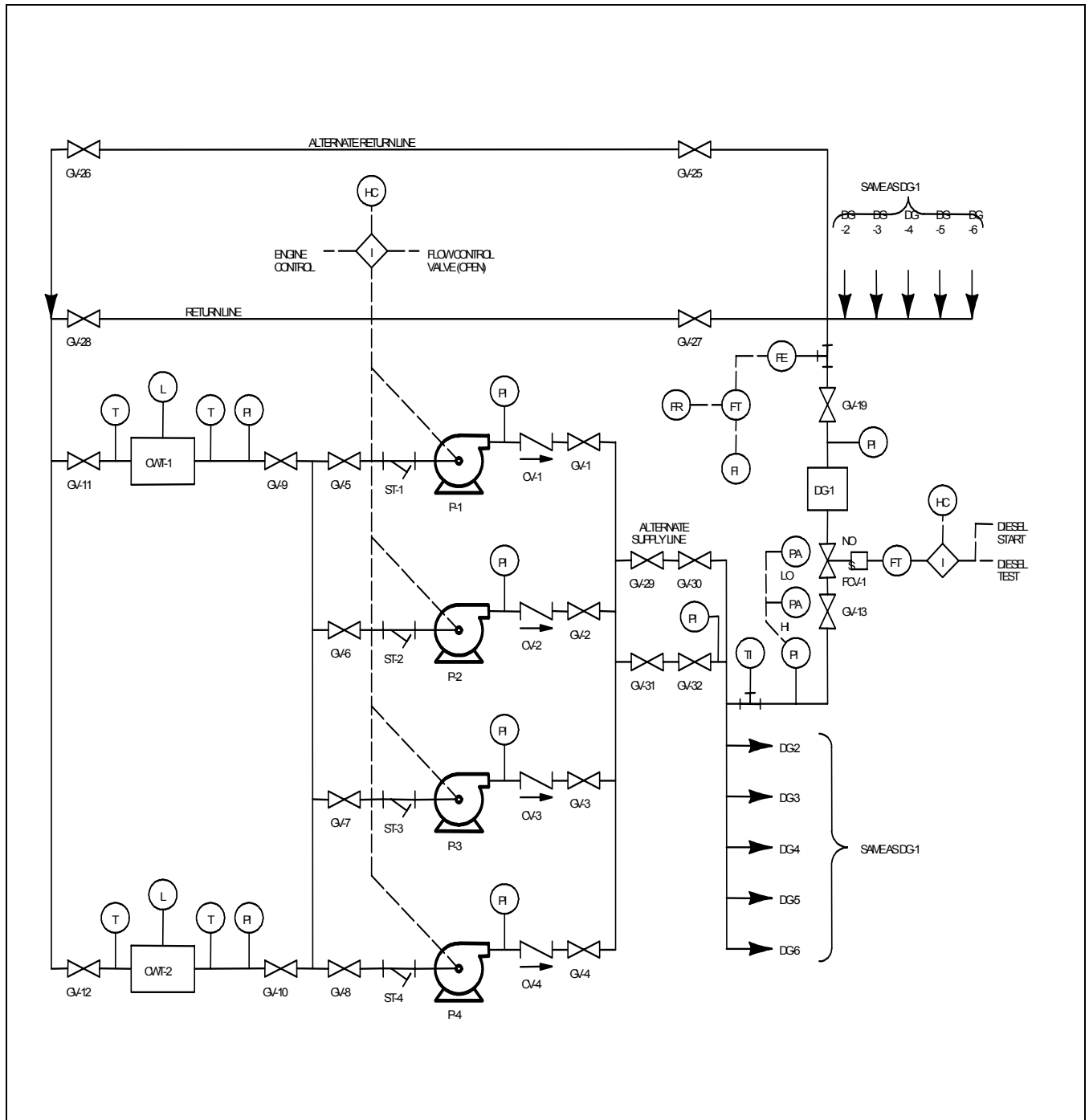


Figure 8-2. Typical cooling water flow & instrumentation diagram

f. Condenser water for mission critical chillers shall be supplied from a dedicated tower and cooling water system. Condenser water systems and cooling towers for non-mission critical HVAC chillers will be separate from the mission critical cooling water systems. If the supply of condenser water for the mission critical chillers is drawn from underground wells or reservoirs, the chemical content of this water must be analyzed to determine the fouling factor. The fouling factor must be considered in the condenser design and in determining the requirements for water treatment equipment in the system. Provide appropriate filtration/strainers to preclude plugging of service lines. Consider blending and bypass systems for the return water loop for severe cold weather conditions.

g. Where possible, cooling water systems shall be selected and designed to avoid once-through cooling as the primary cooling means in order to conserve water and to minimize industrial wastewater. When operating conditions require the use of once-through cooling water, the following requirements must be included in the design.

(1) All once-through cooling water must be supplied from a process water source with appropriate backflow prevention.

(2) Once-through cooling water discharges planned for the sanitary sewer system or the storm sewer system must be approved by the appropriate site environmental organizations and the DPW.

(3) All discharges planned and approved for the storm sewer system must be treated at the source to reduce the residual chlorine content to the allowable site levels.

#### **8-5. Fuel systems**

The main components of a diesel fuel system consist of the main storage tanks, transfer pumps, day tanks, fuel injection pumps, fuel injection nozzles, and filters and strainers. The design of these components should be in accordance with recommendations of the engine manufacturer for optimum performance and warranty protection.

a. Fuel storage capacity shall be divided equally between two main storage tanks when bulk storage facilities are not available. Transfer capabilities between the tanks shall be provided. A recirculation system shall be provided in the tanks. A means shall be provided to inhibit growth of bacteria in the main tanks. Duplex filter separators shall be installed at the inlet to the main storage tanks and each day tank.

(1) Each diesel generator set shall have one day tank. The capacity of day tanks shall not exceed the maximum allowed by NFPA 37, Stationary Combustion Engines and Gas Turbines. All day tanks shall be manifold together and automatically filled to a constant level. Pumps and automatic valves shall be interlockable to remotely shut off fuel to a unit when any of its fire protection systems are activated. Flame arrestors shall be provided on fuel storage tanks when required by NFPA 30, Flammable and Combustible Liquids Code. See figure 8-3 for a typical diesel fuel flow and instrumentation diagram.

(2) Liquid fuel for auxiliary power generating systems is usually stored in buried tanks equipped with vent pipes and manholes. Aboveground tanks may be used for storage at some locations. These tanks usually have provisions for venting, filling, and cleaning. A minimum of two fuel storage tanks is necessary to ensure redundancy and to allow tank cleaning (every two years) and maintenance operations. Storage tanks should allow for checking of settled water accumulation due to condensation and should allow for provisions to remove free water.

**TM 5-691**

(3) Day tanks are normally filled by transfer pumps from the installation's main storage tanks. Provisions should be made to fill the day tanks by alternate means (or directly from safety cans or barrels) if the transfer system fails.

b. The fuel supplies for the emergency generators shall not be used for any other purpose. Fuel storage capacity for systems specified in text (paragraph 10-1a) is recommended for continuous full load plant operation as follows:

(1) Small capacity power system (figure 10-2): three days.

(2) Medium capacity power system (figure 10-3): seven days.

(3) Large capacity power system (figure 10-4): 30 days.

c. Main fuel supply tanks located outside aboveground or underground, or beneath a structure, shall comply with the applicable provisions of NFPA 30. Facilities shall be provided for storage tanks in accordance with NFPA 30 so that any accidental discharge of liquids will be prevented from endangering important facilities and adjoining property, or reaching waterways. The type and grade of fuel shall be identified on the fuel storage

tanks.

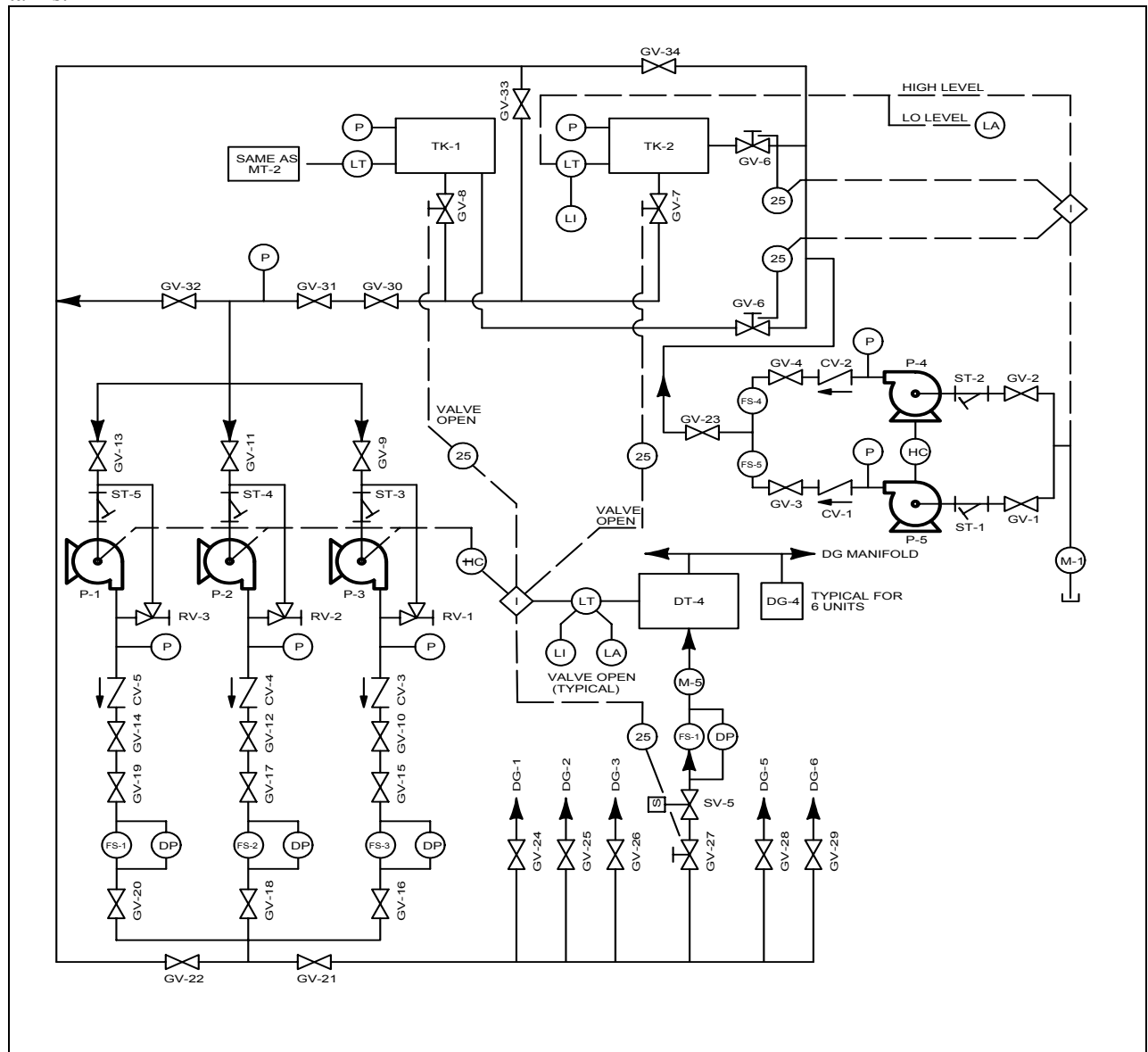


Figure 8-3. Typical diesel fuel flow & instrumentation diagram

d. Underground fuel tanks and piping shall comply with 40 CFR 280, Underground Storage Tanks, and NFPA 30. All underground tanks shall be set on firm foundations and surrounded with at least 6 inches of noncorrosive inert material such as clean sand or gravel well tamped in place. Underground fuel storage tanks and their piping systems shall be double wall construction and shall be protected by a properly engineered, installed, and maintained cathodic protection system in accordance with recognized standards of design. The AHJ may waive the requirements for corrosion protection where evidence is provided that such protection is not necessary.

e. Outside aboveground fuel supply tanks shall be constructed in accordance with the applicable tank specification in NFPA 30. Secondary containment diking shall be around aboveground fuel storage tanks. The volumetric capacity of the diked area shall not be less than the greatest amount of liquid that can be released from the largest tank within the diked area, assuming a full tank.

**TM 5-691**

f. Not more than one integral tank shall be installed on each engine. It shall be securely mounted on the engine assembly, protected against vibration, physical damage, engine heat, and the heat of exhaust piping. Unenclosed day tanks (i.e., tanks not in a room by themselves) supplying engines that drive generators or other equipment used for emergency purposes shall not exceed 660 gallons. Not more than one unenclosed tank shall be connected to one engine. The aggregate capacity of all unenclosed day and supply tanks in a building shall not exceed 1,320 gallons. Day tanks on diesel systems shall be installed in accordance with the manufacturer's instructions based on whether the day tank is above or below the main storage tanks. All day tanks shall be manifold together and automatically filled to a constant level. Gravity fuel return lines shall be sized to handle the potential fuel flow and shall be free of traps so that fuel can flow freely to the day tank or main tank. Quantities of all types of fuels stored in buildings shall meet applicable requirements of NFPA 30, 37, and the AHJ. Day tanks shall be of steel with welded joints. Diking shall be provided in the generator equipment room to contain the largest potential spill from the day tanks. Or a drainage system shall be provided for the generator room that is adequate in size and location to convey any spillage of fuel to a storage tank (inside or outside) or to a safe and approved location outside the structure. Listed generator subbase secondary containment fuel tanks of 660 gallon capacity and below shall be permitted to be installed indoors without diking or remote impounding. A minimum clearance of 3 feet shall be maintained on all sides. The type and grade of fuel shall be identified on the day tanks or integral.

g. Piping and vents for day, integral, and supply tanks shall be in accordance with NFPA 30. Integral and day tanks for diesel generators shall be filled by a closed piping system except when filling from a container when the engine is shut down. Galvanized fuel lines shall not be used. Fuel piping shall be steel. Fuel lines in the generator room are typically located in floor trenches that are covered with removable non-skid steel plates. Trenches are sloped to collection sumps. Approved flexible fuel lines shall be used between the prime mover and the fuel piping for protection against damage caused by settlement, vibration, expansion, contraction, or corrosion. Piping systems shall be substantially supported and protected against physical damage and excessive stresses. Overflows, vents, fuel piping, or fuel tanks shall not be located at or near engine air intake, exhaust piping, mufflers, or filters.

(1) Fuel storage tanks shall be properly sized with vent and fill pipes located to prevent entry of groundwater or rain into the fuel tank. Piping to aboveground fuel storage tanks filled from tank cars or tank vehicles by centrifugal pumps shall be provided with check valves to prevent backflow. Each storage tank should have drain valves for removal of bottom water.

(2) Liquid fuel shall be fed from the day tank to the diesel engine by the engine fuel pump. When the main fuel storage tank is below the elevation of the day tank, a fuel transfer pump shall be installed as close as possible to the supply tank to pump fuel from the supply tank to the day tank.

(3) Day tanks or integral tanks shall be provided with an overflow line or fuel return line in accordance with manufacturer's instructions, a high level alarm, and a high level automatic shutoff. The overflow and fuel return line(s) shall be continuous piping without valves or traps. Capacity shall exceed the delivery capacity of the supply lines.

h. A low-fuel sensing switch shall be provided for the main fuel supply tanks and day tanks. Fuel transfer pumps supplying integral or day tanks shall have stop controls sensitive to a tank's high liquid level.

(1) Fuel in underground storage tanks can be measured by immersing a calibrated dip stick in the tanks. For day tanks, a glass sight gauge or a float actuated gauge can be used to measure the quantity of liquid fuel. Remote indication of the fuel levels in the storage tanks and day tanks shall be provided at the control room.

(2) Sufficient valves shall be provided to control flow of liquid fuel in normal operation and to shut off the flow of fuel in the event of a pipe break. Where used, solenoid valves, both in the fuel line from the supply tank(s) to the generator set and in the water-cooling lines, shall operate from battery voltage. Means shall be provided for manual (nonelectric) operation of these solenoid valves, or a manual bypass valve shall be provided. The manual bypass valve shall be visible and accessible and its purpose identified. This fuel valve shall not be the valve used for malfunction or emergency shutdown.

#### **8-6. Air start systems**

Some larger diesel engines may use an air starting motor instead of an electric battery starting system. The use of air starting systems shall be permitted where recommended by the manufacturer of the prime mover, subject to approval of the AHJ. Pneumatic air starter motors are highly reliable. Air starting motors are suitable on diesel generators ranging from about 85 kW up to the largest diesel engine generators. Air starting motors should be supplied from the generator manufacturer with the engine. See figure 8-4 for a typical starting airflow and instrumentation diagram.

- a. Air starter motors develop enough torque to spin the engine at twice the cranking speed in half the time required by electric starter motors. Compressed air at a pressure of 110 to 250 psi is stored in storage tanks, regulated to 110 psi, and piped to the air starting motors. Appropriate allowances must be made for pressure drops in the air distribution lines.
- b. A check valve installed between the compressor and the storage tanks will prevent depletion of compressed air should the air system fail. Air compressors are driven by electric motors wired to the emergency power source (i.e., diesel generators) with back-up gasoline driven engines for added starting protection. For large central station air supply systems with an abundance of air receiver capacity, a gasoline driven backup motor for the air compressor may not be necessary.
- c. Air starting motor supply piping should be short, direct, and at least equal in size to the air motor intake opening. Steel piping is preferable and should be supported to avoid stresses on the compressor. Flexible connections between air motor and piping are required. Deposits of oil-water mixtures accumulating in receiver tanks and piping are removed by traps. Lines shall slope toward these traps installed at intervals in the lines.
- d. Air cranking systems may freeze at low ambient temperatures since water vapor in the compressed air may freeze during expansion in temperatures below 0°C (32°F). Therefore, components of the air starting systems should be located with heated mechanical equipment rooms to minimize the potential for freezing. The use of an air dryer or a small quantity of alcohol in the starter air tanks can also help prevent freezing.
- e. Air receivers shall meet American Society of Mechanical Engineers (ASME) pressure vessel requirements and be equipped with a safety valve and pressure gauge. Air starting receivers shall be sized in accordance with requirements of the diesel generator and air starting motor manufacturers.
- f. Air starting receivers shall be sized for the specified number of starting attempts and crank duration as specified in NFPA 110, Emergency and Standby Power Systems. Diesel prime movers shall be permitted to use continuous cranking methods. Upon starting and running the diesel prime mover, further cranking shall cease. Two means of cranking termination shall be utilized so that one serves as backup to prevent inadvertent starter engagement.
- g. Thermostatically controlled jacket water heaters shall be used to reduce cranking time and promote more dependable starts.

## TM 5-691

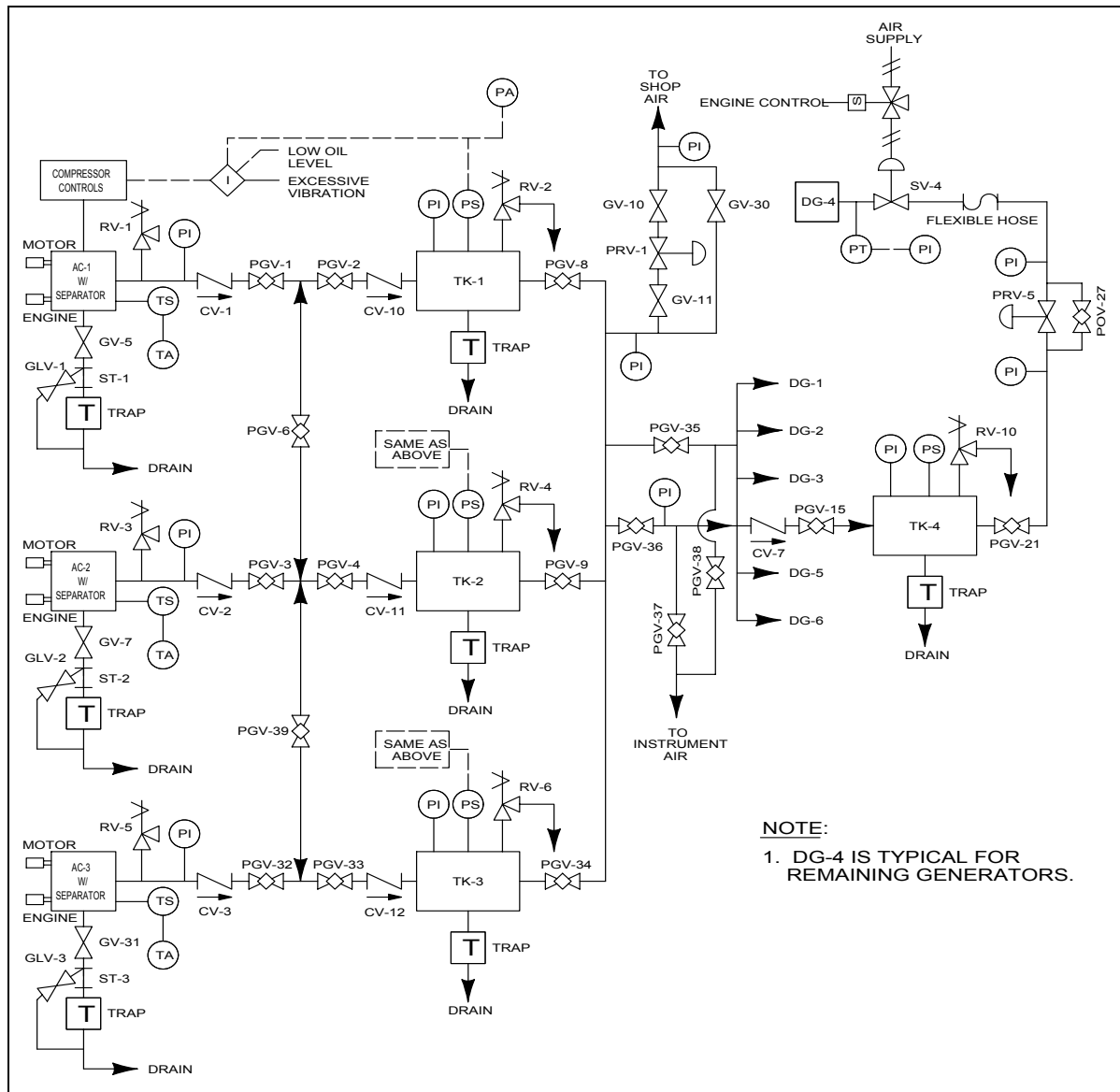


Figure 8-4. Typical starting air flow & instrumentation diagram

### 8-7. Instrument air systems

Design guidance for the design of low pressure instrument air systems with a maximum design operating pressure of 125 psig shall be in accordance with TM 5-810-4, Compressed Air. Design steel and copper tubing systems to meet the requirements of ANSI B31.3. When an instrument air system is used, the instrument air receivers shall be sized to meet the maximum demand for at least one hour. The air shall be dried to a constant maximum pressure dew point of 1.7°C (35°F) or atmospheric dew point of -23.3°C (-10°F) at 7.3 kg/cm<sup>2</sup> (100 psig). When air is used for prime mover starting, there shall be an interconnecting emergency line from the air starting receivers to the instrument air system. Refer to figure 8-5 for a typical instrument air flow diagram.

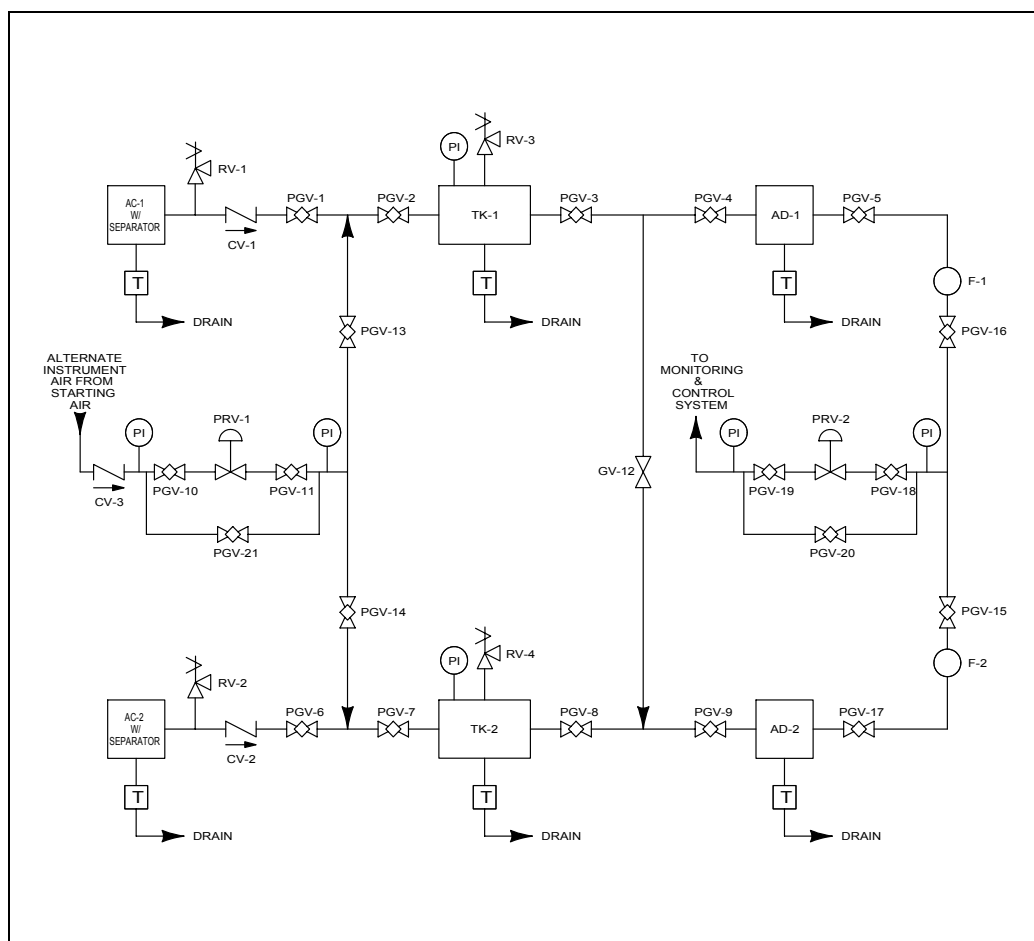


Figure 8-5. Typical instrument air flow diagram

## 8-8. Lube oil systems

Storage and automatic transfer facilities shall be provided for both clean and dirty lube oil. The storage shall provide for 30-day makeup requirements plus an oil change for all equipment. The tank system shall be sized to pump non-refreshed for a minimum of one hour. Crankcase or oil reservoir vents and piping shall be in accordance with NFPA 37.

## 8-9. Water treatment

Treatment of cooling water systems, potable water supplies, and wastewater effluent shall be in accordance with the following criteria.

- a. Water treatment equipment and facilities shall be provided to protect the cooling water system against such damaging effects as corrosion, inorganic scaling, and organic growths. Installation of nonchemical devices such as magnetic, electromagnetic, and similar devices that claim to soften water or reduce scale in water systems, heating and cooling systems, or boilers are prohibited.
- b. Installation commanders will provide facilities to disinfect water supplies in accordance with TM 5-660, Maintenance and Operation of Water Supply, Treatment and Distribution Systems. In coordination



**TM 5-691**

with the Installation Medical Authority (IMA), the DPW will disinfect new and repaired water mains, storage tanks, wells, and equipment in accordance with American waterworks Association (AWWA) C651, Disinfecting Water Mains; AWWA C652, Disinfection of Water-Storage Facilities; AWWA C653, Disinfection of Water Treatment Plants; and AWWA C654, Disinfection of Wells, following construction, repairs, installation of taps, or contamination situations.

c. Whenever possible, wastewater effluent should be sent to a suitable treatment plant which can treat the effluent to meet NPDES permit requirements.

**8-10. Corrosion protection**

Protect underground piping against corrosion either by the use of resistant materials or other protective measures. Use naturally resistant materials when adequate protection is provided by their use. Site soil and groundwater conditions (e.g., soil corrosivity) shall be considered during the selection of the corrosion protection system(s).

a. Metallic water supply and metallic wastewater collection lines should be bonded and coated. External surfaces that are in contact with soil and all internal surfaces of steel water storage tanks should be protected from corrosion by a cathodic protection system.

b. If buried fuel systems require cathodic protection, the protection system shall be installed at the same time as the pipeline. Design piping system to reflect the special requirements of cathodic protected systems addressed in chapter 10, Electrical Systems. Install adequate test stations to evaluate the performance of the cathodic protection system after installation. Terminate test stations aboveground in accordance with chapter 10, Electrical Systems. Connection at joints shall ensure electrical continuity except where insulating joints are installed. Insulating joints shall be used to electrically isolate protected sections from non-protected sections and from neighboring metallic structures. Where ferrous pipe is installed within the distribution system, insulating couplings shall be installed to preclude galvanic corrosion. Cathodic protection for underground flammable/combustible liquid storage tanks shall comply with NFPA 30. Coordinate the type of cathodic protection required with the electrical design.

**8-11. Protection**

Piping penetrations through shielded mission critical areas should be protected properly to avoid degrading the EMP shielding effectiveness.

a. Three types of piping penetrations need to be considered:

- (1) A metallic pipe that carries a conducting fluid (e.g., steel chilled water pipe)
- (2) A metallic pipe carrying a dielectric fluid (e.g., steel air pipe)
- (3) A dielectric pipe carrying a dielectric fluid (e.g., plastic air hose)

b. A fourth possibility, a conducting fluid in a dielectric pipe (or dielectrically lined metal pipe such as glass-lined steel) cannot be EMP protected properly and must be avoided.

c. The waveguide-beyond-cutoff principle is used for piping penetrations. For a metal pipe, a circumferential weld to the primary shield is required so that current flowing in/on the pipe can be discharged onto the outer surface of the shield. The interior pipe wall serves as the waveguide. The inside diameter (d) should be less than or equal to four inches to provide a cutoff frequency of 1.73 GHz. The continuous length (l) adjacent to the penetration must be a minimum of five diameters to attenuate by at

least 100 dB at the required frequencies. If a pipe is greater than four inches, inside diameter is required and protection options include:

- (1) Subdivide into two (or more) pipes that satisfy the dimensional requirements.
  - (2) Insert a honeycomb filter inside the pipe and treat the penetration as described for air distribution penetrations. If this method is used, the higher pressure drops incurred must be taken into account when sizing the chilled water pumps.
- d. If a dielectric pipe with dielectric fluid penetrates through a metal waveguide sleeve, the sleeve has the same dimensional requirements that apply to metallic pipe. It is common practice to fill the waveguide sleeve with epoxy or similar material to prevent the insertion of conductors (e.g., conducting fluids, wires, pull wires). Dielectric pipes greater than four-inch inside diameter follow the same guidelines as metal pipes greater than four inches as discussed above.
  - e. Controls for motorized valves, pump motor controls, and pressure and flow sensors, etc., must be protected to ensure their operation during an EMP event. The basic protection method is to surround the controls with a separately grounded conducting barrier.

## **8-12. Water distribution system**

This paragraph covers the utility water distribution system, piping downstream of the water treatment plants, cooling towers, and mechanical chiller equipment excluding fire protection systems which is covered in chapter 6, Fire Protection Systems. Requirements for trenching, routing, and burial of underground pipelines is defined in chapter 4, Civil and Site Engineering and Waste Management.

- a. Size water lines using the Darcy-Weisbach formula by extracting data from the Moody diagrams for friction losses in water pipe.
- b. Water mains shall be designed in accordance with the following criteria:
  - (1) Design the distribution system to use the looped-grid type system providing two-way flow with sectional valving arranged to provide alternate water flow paths to any point in the system.
  - (2) Design water system to meet requirements of the National Standard Plumbing Code or other building code applicable to the region.
  - (3) Design water mains supplying fire protection systems and fire hydrants to meet further requirements of NFPA 24, Private Fire Service Mains.
  - (4) Design water mains to maintain a normal operating pressure range of 40 to 100 psi in distribution mains and building service lines. Design mains for a minimum pressure rating of 150 psi.
  - (5) Design system to maintain adequate residual pressure for proper operation of internal fire protection systems (sprinklers, etc.).
  - (6) Where service lines enter the building, provide suitable flexibility to protect against differential settlement or seismic activity in accordance with the National Standard Plumbing Code or NFPA 13, Installation of Sprinkler Systems.

**TM 5-691**

(7) Building service lines larger than 2 inches in diameter shall be connected to the distribution main by a rigid connection and shall have a PIV located below frost line. Risers from frost line to floor lines of building shall be adequately insulated.

(8) Distribution system mains shall have a minimum depth of cover below the frost line. Additional cover or protection shall be provided at railway crossings and in high traffic areas.

c. Potable water mains shall be designed in accordance with the following criteria.

(1) Locate potable water lines in separate trench from sewer lines. Avoid routing lines under pavement (except at road crossings) or other inaccessible locations.

(2) Where feasible, potable water lines shall not be routed within ten feet of sewers or force mains.

(3) Where potable water mains must cross sewers or force mains, water mains shall pass two feet above the sewer or force mains. Where insufficient cover precludes such vertical separation, the sewer or force main shall be ductile iron pipe or shall be fully encased in concrete for a minimum distance of ten feet to each side of the water line crossing. Where feasible, sewer or force main pipe joints shall not be located within three feet of such crossing unless the joint is encased in concrete.

(4) Design the distribution system to deliver peak potable flow of 2 1/2 times the average daily demand plus any special demands, at a minimum residual pressure of 30 psig at ground elevation.

(5) Design potable water heaters that also serve fire protection requirements to satisfy fire protection requirements plus 50 percent of the average potable water requirements plus any process demands that cannot be reduced during a fire.

(6) Use no lead solder for copper piping in potable water systems.

d. Install reduced pressure type backflow preventer (RPTBP) or other approved device at branch lines supplying process water systems. Locate backflow preventer within five feet of floor level. Design to prevent cross connections between potable water and all other systems, either liquid or gas.

e. The following valves and accessories shall be included in the design of the water distribution system.

(1) Provide accessible shut-off valves at branches serving floors or multiple fixture arrangements, at risers serving multiple floors, and at equipment or appurtenances.

(2) Design combined fire water and potable water supplies to each building with valving that permits potable water system shutdown without affecting the fire water system.

(3) Use of pressure relief and surge relief valves shall be considered to preclude system damage from water hammer.

(4) Provide manufactured water hammer arresters where necessary.

(5) Install air release and vacuum valves at high points and in long supply mains.

(6) Provide a vacuum breaker at all hose connections on potable water system.

(7) Provide stop valves at each plumbing fixture.

(8) Provide drain valves to drain the plumbing system. Provide manual air vents at high points in the system.

(9) Provide ASME code-stamped tanks for hot water generation equipment when of sufficient capacity, water temperature, or heat input rate to be within the jurisdiction of the ASME Boiler and Pressure Vessel Code, Section VIII. Provide ASME-approved relief devices on hot water tanks.

(10) Provide fail-safe pressure balance type tempering valves (anti-scald) where required for personnel protection.

(11) Provide anti-sweat insulation for cold water lines inside buildings. Provide insulation for hot water lines inside buildings when required for heat conservation or personnel protection.

### **8-13. Potable (domestic) water supply**

Potable water is defined as water that has been treated so that it may be used for drinking, personal, or culinary purposes. Effluent from the water treatment plant is pumped to storage tanks and distributed through headers to usage points. Design potable water system to comply with 40 CFR 141, National Primary Drinking Water Regulations.

a. The design shall be based on a limited-water site. There shall be sufficient on-site water (e.g., storage tanks or well) to supply critical systems for a period of seven days minimum. Larger storage may be required if estimated supply system downtime is greater. The domestic water supply shall be used for lavatories, mechanics' and janitorial sinks, and drinking fountains. The system shall supply water to the hot water system, water treatment equipment, chilled water system, and water make-up piping. A domestic hot water system shall be provided.

b. Water from the supply source shall flow into a hydro-pneumatic tank rated for a pressure sufficient to overcome pressure losses in distribution plumbing and to maintain approximately  $2.8 \text{ kg/cm}^2$  (40 psig) at any outlet. This tank shall supply the domestic water plumbing system. A domestic hot water storage tank shall be provided.

### **8-14. Eye washes and safety showers**

Eye wash and safety shower water is a special use of potable water that is supplied through an independent header system. Safety shower water has special valves to prevent inadvertent disabling of the system.

a. Design safety shower system to feed off potable water supply upstream of building shutoff valve. Install locked-shield type valves, which can be locked in the open position, or other lockable type valves in the safety shower supply water lines. Type K copper shall be used for belowgrade potable water supply distribution for two inches and less and ductile iron shall be used for sizes larger than two inches based on the Standard Plumbing Code. Emergency eyewashes, showers, or combination eyewash showers shall be provided in areas where corrosive or other skin- or eye-irritant chemicals are stored, handled, used, or dispensed. Provide safety showers, eyewash, or combination units in accordance with ANSI Z358.1, Emergency Eyewash and Shower Equipment, and 29 CFR 1910.151.c, Occupational Safety and Health Administration (OSHA).

b. Eye wash fountains and emergency safety showers shall be included in the battery room, the diesel generator room, and maintenance areas.

**TM 5-691****8-15. Process water supply**

Process water is defined as water supplied from the potable water system downstream of a RPTBP approved by the University of Southern California, Foundation of Cross Connection Control and Hydraulic Research or downstream of other approved devices. Do not use process water for any personal or culinary use. Process water systems are once-through or total consumption-type systems. Identify each use point supplied by process water downstream of a vacuum breaker by signs meeting OSHA requirements. Design, operation, and maintenance of cross-connection control components (i.e., backflow prevention devices) will be in accordance with TM 5-660. A process water hose bib shall be provided in the generator equipment room for wash down of floors and equipment.

**8-16. Plumbing and sanitary sewer systems**

Guidance for the design of plumbing systems, together with the criteria for selecting plumbing materials, fixtures, and equipment shall be in accordance with TM 5-810-5, Plumbing. The plumbing system shall provide adequate water drainage for the fire protection systems serving mission critical, computer, and electronic equipment areas.

- a. Sanitary drains convey human waste products, shower discharges, wash water waste products, and other liquids that require treatment in a sewage plant before discharge to a receiving stream. The sanitary sewer systems shall be capable of handling domestic sanitary sewage for the facility. All proposed connections to the sanitary sewer system shall be approved by the appropriate site environmental compliance organization.
- b. Design the sanitary drain system to be as simple and direct as possible. Provide for known future expansion. Sanitary sewer drains shall not be connected to the storm drain system. Drains from safety showers shall be contained or collected as appropriate on each project. Where feasible, do not route sewers and force mains under buildings or other permanent structures.
- c. Sewage lift stations and force mains shall not be used unless approved by the DOD AHJ. Sewers and force mains shall be sized to accommodate the estimated daily and maximum discharges for the initial and final years of the design period. Hydraulic design of wastewater collection systems shall comply with TM 5-814-1, Sanitary and Industrial Wastewater Collection, Gravity Sewers and Appurtenances, and TM 5-814-2, Sanitary and Industrial Wastewater Collection-Pumping Stations and Force Mains. All wastewater collection systems shall be designed for gravity flow unless such systems are not economically feasible. Design sanitary sewer system for velocities as listed in chapter 4.

**8-17. Storm and process drains**

This section covers piping for storm and process drains located within the building structure. Civil and Site Engineering and Waste Management, chapter 4, has responsibility for all exterior gravity drains (i.e., sanitary and storm drains) and wastewater treatment systems.

- a. Storm drains convey rainwater or other liquids that do not require treatment before discharge to receiving stream. All proposed drain connections to the storm drain system shall be approved by the appropriate site environmental compliance organization. Design storm drain lines to meet the requirements of National Standard Plumbing Code.
- b. Chemical or process drains convey liquids that cannot be discharged into either sanitary or storm systems without further waste water treatment. Design stainless steel chemical drains to meet the requirements of ANSI B31.3. Design drain lines for gravity flow where economically feasible. Provide

clean outs in stainless steel gravity flow drain lines similar to those required by the plumbing code for cast iron (CI) drains.

#### **8-18. Condensate drains**

A waste disposal piping system shall be provided for condensate drains from air compressors, air-conditioning equipment, and similar overflow, bleed, and drain connections. These wastes shall flow through oil-water separation devices prior to entering the site sanitary sewer system.

#### **8-19. Cooling tower blow down and drains**

The blow down from cooling towers shall be piped into the site storm drain system if chlorine and chemical contamination levels are acceptable. Environmentally safe chemicals should be considered for the design of the cooling tower(s) chemical treatment systems. Cooling tower blow down shall be discharged to an appropriate wastewater or process drain system when disposal is not permitted through the facility storm drain system because of chemical contamination. Appropriate disposal of cooling tower blow down shall be approved by the site environmental organization.

#### **8-20. Seepage and sump collection**

Seepage and leakage into belowgrade structures and basements shall be collected in sump pits provided for this purpose. The leakage shall be piped into the facility storm drain system after it has passed through oil-water separation devices. Sumps and dikes shall be provided in the diesel generator room for collection of spilled oils and fuel. Sump pumps shall pump accidental spills to a wastewater treatment facility or wastewater collection system capable of safely disposing of spilled materials. Containment barriers shall be installed in sump/trench areas between the generators to prevent an oil fire from spreading the length of the power plant.

#### **8-21. Insulation**

Provide insulation of exterior aboveground and underground distribution systems and equipment for condensation prevention, minimization of energy loss, and for personnel safety. The design of insulation systems shall be based on the Thermal Insulation Manufacturers Association (TIMA) Economic Thickness Manual. Design insulation for lines subject to freezing.

a. All insulation material, media used to apply insulation, and jacketing material shall have a maximum flame spread of not more than 25 fuel-contributed and smoke-developed ratings of not over 50 when tested using UL, 723, Safety Test for Surface Burning Characteristics of Building Materials. Exception to the smoke-developed rating of 50 shall be made for exterior underground piping. Asbestos or asbestos-containing materials shall not be used.

b. Specify that all insulation installed outside aboveground, in tunnels, and in manholes be provided with a metal jacket (either factory or field installed). Specify cellular rubber insulation and metal jacket for all electric traced lines and auxiliaries. Specify underground insulation considering the possibility that water infiltration will cause physical damage or loss of thermal characteristics.

**TM 5-691****8-22. Water storage tank**

Steel water tanks, stand pipes, and reservoirs shall comply with NFPA 22, Water Tanks for Private Fire Protection, and American Water Works Association (AWWA) D100, Welded Steel Tanks for Water Storage.

**8-23. Pressure vessels**

Specify that tanks and pressure vessels qualifying by size and pressure be designed, fabricated, inspected, and stamped in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII.

**8-24. Valving**

Piping system valves shall be provided as noted below. All valves will be tagged with their respective valve numbers as shown on the drawings. Safety valves shall be National Board stamped and have lever operators.

- a. Isolation valves shall be installed at maximum intervals of 5000 feet on long supply lines and at maximum intervals of 1200 feet on main distribution loops, feeders, and all primary branches connected to these lines.
- b. Provide block valves on all service branch lines (except as prohibited herein) to maintain service during maintenance. Locate block valves for all branch headers as close as practical to the main headers. Provide block (shut off) valves at all plumbing fixtures and in all looped headers. Block valves are prohibited on relief valve lines, except for locking type allowed by the ASME code.
- c. Provide check valves on all pump discharge piping.
- d. Pressure-reducing valves shall be provided where service pressure or devices exceed the normal operating range recommended by the manufacturer. Whenever a pressure-reducing valve's failure may cause equipment damage or unsafe conditions, a pressure-relief valve shall be provided downstream of the reducing valve. Show type, size, pressure setting, and capacity of all pressure-reducing and relieving devices on the drawings. Design pressure relieving devices in accordance with ASME Code, Section VIII.

**8-25. Piping systems maintenance**

Loop piping headers where practical to provide continuous service during routine maintenance. Design consideration shall be given to providing sufficient shutoff valves to isolate equipment to facilitate maintenance and to providing drain valves for cleaning and flushing the emergency generator cooling systems. Provide working access where maintenance or replacement of equipment, valves, or other devices may be necessary.

**8-26. Piping above computer and electronic equipment areas**

Steam, water, or horizontal drain piping should not be in the space above the suspended ceiling and over computer and electronic equipment other than for sprinkler system use.



## CHAPTER 9

### EMERGENCY GENERATOR SYSTEMS

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#### 9-1. General mechanical systems design

This chapter describes the basic system requirements for on-site generating units at C4ISR sites. Specific information about the major components and operation of a generating system and auxiliaries, such as the prime movers, lubricating systems, etc., can be found in TM 5-685, Operation, Maintenance, and Repair of Auxiliary Generators.

- a. The design agency shall specify that mechanical equipment, such as hoists, vibration isolators, lubrication systems, radiators, etc., shall be of industry-standard sizes and types.
- b. The design agency shall specify that the construction contractor procure a list of required machine lubricants from the equipment manufacturers. This list shall include special lubricants for unusual operating requirements such as extreme temperatures.
- c. The design agency shall specify that equipment used to service and support principal facility equipment incorporate standards that create uniformity and interchangeability. When practical, the design agency shall standardize equipment used in quantities, such as cranes, lifts, and hoists, by specifying that it be purchased from one manufacturer.
- d. Color-coded symbols per American National Standards Institute (ANSI) A13.1, Scheme for the Identification of Piping Systems, shall be used to identify the temperature, pressure, content, and direction of flow through air, water, lubricant, and fuel lines. Rotation codings on motor and generator housings shall be used to indicate the direction of rotation for normal operation of the machine.

#### 9-2. Generator room or building

The generator room shall incorporate the following design features:

- a. The generator room or building will be provided with an overhead I-beam rail or movable structure that will support a chain fall hoist to allow removal of cylinder heads, cylinder liners, pistons, etc. Adequate ceiling height and area lighting will be considered in the design of the generator room or building.
- b. A generator and its prime mover should be set on a single, uniform foundation to reduce alignment problems. The foundation should be in accordance with manufacturer's recommendations for proper support of equipment and dampening of vibrations. Foundation, prime mover, and generator should be mechanically isolated from the building floor and structure to minimize or eliminate transmission of vibrations to the permanent structure. Vibration isolators, as recommended by the manufacturer of the emergency generator, shall be installed either between the rotating equipment and its skid base or between the skid base and the foundation or inertia base. All mechanical and electrical connections to the generator set should allow for vibration isolation.
- c. Design the generator room or building for noise attenuation in accordance with OSHA standards. Exhaust noise can be attenuated by using proper mufflers. To attenuate other noises, use line-of-sight acoustical barriers, acoustical enclosures, sound attenuating duct treatment, or install the generators away from critical areas.



TM 5-691

- d. The space around the generators should permit easy access for maintenance and repair.
- e. The generator room wall shall be equipped with air intakes. The air intakes shall be in accordance with the manufacturer's requirements and dependent on the sizes and quantity of generator sets.

### 9-3. Diesel engine cooling systems

Diesel engines shall be liquid cooled. Liquid coolant systems consist of unit-mounted or remote fan-cooled radiators and water-cooled heat exchangers. Adequate freeze protection shall be provided for the engine cooling system.

- a. Unit-mounted radiators are installed on the base of the generator set in front of the engine. The mounted radiator with a radiator fan is typically the most economical method of cooling an engine. The air stream drawn over the engine by the fan is pushed through the radiator. This action provides surface cooling for the engine together with cooling of the engine coolant in the radiator. Radiator and fan cooling is independent of potentially interruptible utility supplied cooling water. In addition, coolant can be treated rust inhibitors, anti-freeze, etc. Refer to figure 9-1, typical diesel engine liquid cooling system with radiator.

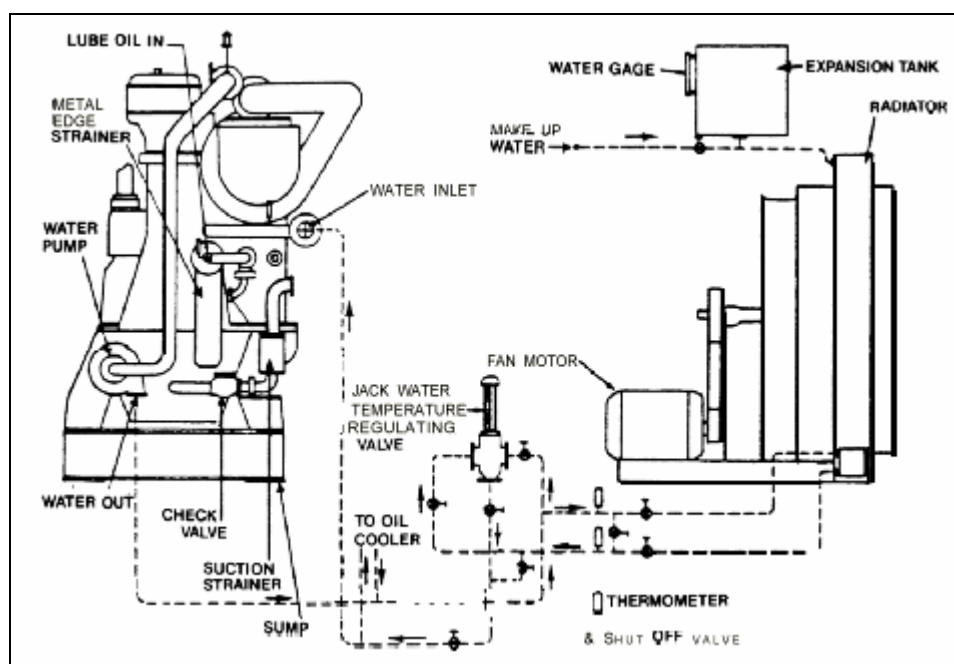


Figure 9-1. Typical diesel engine liquid cooling system with radiator

- b. Some installations require the radiator and fan be mounted separately from the generator set. While these systems offer more versatility, might require less power for generator room ventilation, and can use low-noise fans, these systems are more expensive in original cost than the unit-mounted radiators. Also, application of a remote radiator requires careful planning and design to ensure proper cooling of the equipment. The design of this type of cooling system requires a qualified consulting engineer with hydraulic cooling system design experience. Remote radiator cooling installations will require high altitude electromagnetic pulse (HEMP) protection if site is HEMP protected.

c. Heat exchanger cooling eliminates the necessity of both a radiator and the associated cooling fan. Raw water or cooling tower water is used for cooling the engine coolant. Heat is radiated from the engine coolant to the heat exchanger. The heat exchanger radiates heat to the raw water or cooling tower water. The heat exchanger consists of tubing within a surrounding “shell.” Engine coolant in the heat exchanger does not mix with the raw water or cooling tower water in the tubes. Raw water or cooling tower water passing through the tubes absorbs engine heat from the separated engine coolant in the heat exchanger shell. This type of cooling system also requires a qualified consulting engineer with hydraulic cooling system design experience for proper cooling of the equipment.

d. Cooling towers and evaporative coolers are both used to dissipate diesel engine heat to the atmosphere. They may be used where ambient air is sufficiently cool and dry (low relative humidity) to absorb water vapor. As water is sprayed or divided into many small streams, some will evaporate to the passing air. The air which is now moist may be warmed by the water (if the water was originally warmer than the air), thus removing more heat from the water. In a cooling tower, the fluid to be cooled is exposed to the air. Approximately 80 percent of the heat removed is due to evaporation. The tower may use atmospheric draft or fans to move the air. Makeup water is required to replace that lost by evaporation or entrained spray. Water treatment and blowdown are necessary because salts are concentrated by the evaporation. In an evaporative cooler, the coolant passes through tubes. The tube bundle lies inside the cooling tower. The cooling tower spray and air movement cool the tubes but do not mix with the coolant. A 30-minute backup supply of make-up water shall be provided for cooling towers and evaporative coolers serving C4ISR facilities.

#### **9-4. Engine coolant heaters**

The diesel generators must be easily started in all seasons of the year. Thermostatically controlled engine coolant heaters shall be provided to increase starting reliability, increase engine life, and increase generator set load acceptance. The engine water jacket heaters shall maintain the jacket water temperature at not less than 90°F. All water jacket heaters shall be automatically deactivated while the diesel engine is running. Thermostats are used to control operation of the heaters by sensing coolant or engine block temperature. Engine coolant heaters shall be connected to the normal (commercial) power source.

#### **9-5. Lubrication system**

The bearings and moving parts of all diesel engines are lubricated by a full pressure lubrication system.

a. Lubricating systems of small engines usually are self-contained in the crankcase or a separate oil pan underneath the engine contains all the oil used in the system. Smaller engines will have many of the system elements used in the larger engines, such as a feed pump, piping, valves, controls, engine internal oil passageways, oil sump, oil filter, sampling valves, and transfer system for adding new oil and removing used oil from the engine. See figure 9-2 for a typical diesel engine lubrication system.

b. Because large engines require a large quantity of oil, a separate oil sump tank is installed to receive oil from the crankcase. The lubricating oil pump draws oil from the sump tank through the strainers. Oil is then discharged, under pressure, into the oil cooler. The oil then goes to a header, located on the engine, with branches leading to the various parts of the system.

c. Circulating lubricating oil absorbs heat from the engine. Frictional heat is absorbed from the bearings. The oil film on the cylinder walls absorbs heat from the combustion space before this oil film drains into the crankcase. Therefore, heat must be dissipated from the oil by an oil cooler to keep the

TM 5-691

temperature below manufacturer's recommendation. Oil coolers should be placed in the oil circuit after the lubricating oil filter. The oil filter then handles hot oil of lower viscosity than if it received cooled oil. The filter performance is better and the pressure drop through it is less with this arrangement. Coolers are usually mounted on the side of the engine or on the floor alongside of the engine base. Cooling water passes through the oil cooler before entering the engine jacket. Consideration shall be given to providing diesel engine prime movers with lubricating oil heaters to ensure quick starting.

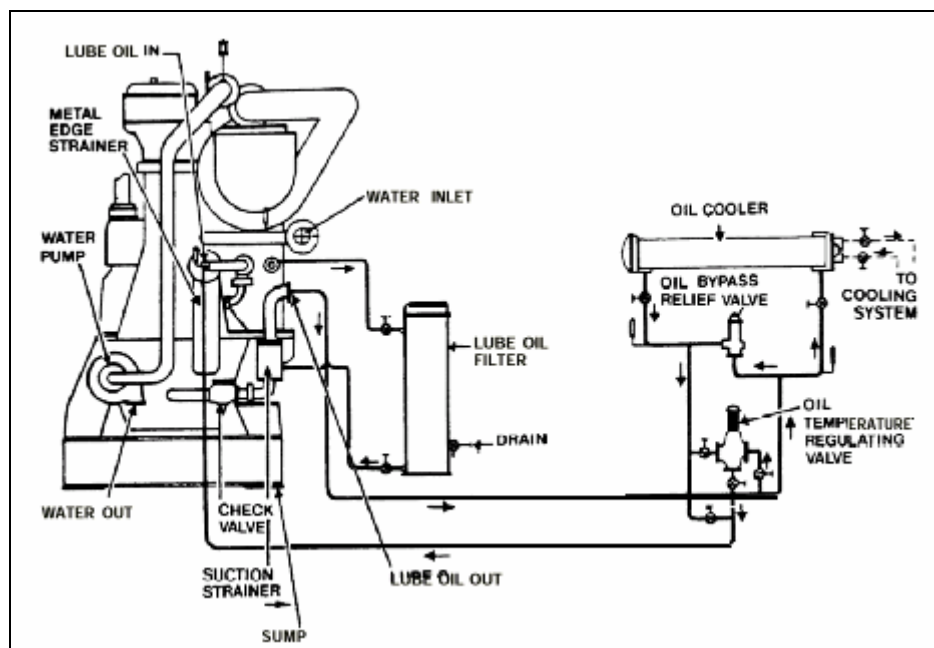


Figure 9-2. Typical diesel engine lubrication system

### 9-6. Engine protection

Engines of ten horsepower or more shall be equipped with automatic engine shutdown devices for high jacket water temperature or high cylinder temperature, low lubricating oil pressure or oil level, and engine overspeed/high speed. If the generator engine will be constantly attended, an alarm shall be permissible in lieu of the shutdown devices.

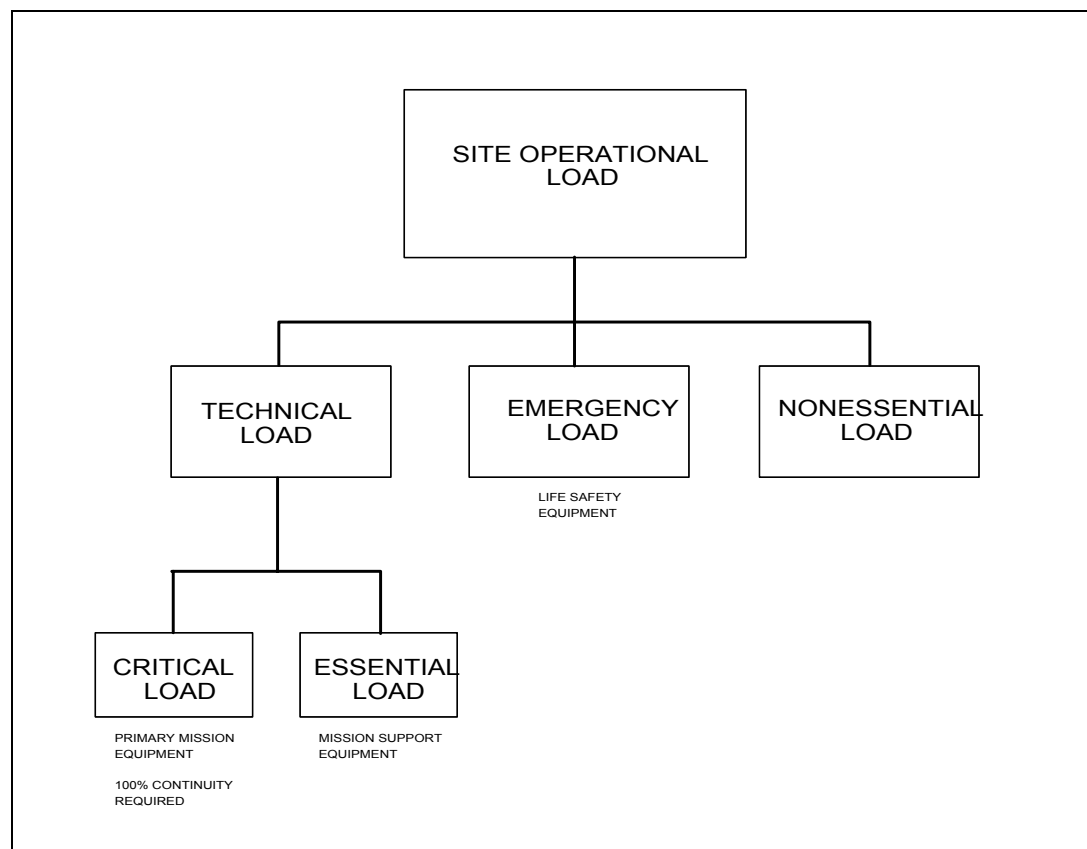
## CHAPTER 10

### ELECTRICAL SYSTEMS

#### 10-1. General electrical design

This chapter provides criteria for the design of highly reliable electrical power systems to serve C4ISR sites. Electrical systems shall comply with the current edition of NFPA 70 and shall be designed so that all components operate within their capacities for initial and projected loads.

a. Electrical peak power demands shall be determined for the specific C4ISR site. Demands shall be calculated based on the total connected load and conservative use of demand and diversity factors between different equipment, systems, and facilities to ensure that adequate capacity shall be available to supply the equipment installed initially and any anticipated future loads. For large systems, a load-shedding and restoration scheme shall be provided to compensate for sudden changes in available power caused by loss of any commercial (prime) power source, by loss of one or more on-site (standby) generating units, or by loss of both power sources. Typical site operational load will generally consist of a technical load, an emergency load, and a non-essential load. See figure 10-1.



*Figure 10-1. Hierarchy of electrical loads*

(1) Critical loads are that portion of the technical load used to successfully accomplish the site missions and having a requirement for 100 percent continuity in power service, such as from the UPS

**TM 5-691**

system. These loads also include any equipment which, upon loss of power, will create an unacceptable impact on the mission or mission equipment. These loads shall not be shed intentionally if sufficient power is available to supply them. Less critical loads can be shed manually in instances when sufficient power is not available to supply all critical load demands. Critical loads shall be restored first if there is a total power outage and as soon as possible after partial or total power is restored.

(2) Essential loads are that portion of the technical load that directly supports routine accomplishment of site missions. Loads include general lighting and power systems; heating, ventilating, and air conditioning (HVAC); and similar loads which can tolerate short-term power outages without loss of data or without adversely affecting vital missions. All systems other than the critical equipment/systems (CES) are to be considered essential if they must operate to supply CES directly. This includes the support loads for the critical loads, security lighting, intrusion detection, entry control, and security monitoring equipment. These load types shall be shed second and restored before non-essential loads, but not before the critical loads are restored if power to critical loads is also lost.

(3) The emergency load consists of emergency lights, exit lights, fire suppression systems, and similar life-safety loads. Emergency loads shall be provided with their own battery backup systems or emergency generator capable of coming on-line within ten seconds. These loads shall not be served from the UPS supplying critical loads.

(4) The non-essential load is that portion of the operational load that indirectly supports the operations at the C4ISR site. This generally includes exterior and interior lighting and loads associated with administration and housing functions. Non-essential loads shall be shed first and restored last during power shortages and restoration of power. The design of the power system for non-essential support systems uses radial feeders and non-redundant items of equipment. Conventional design practice shall be followed, with the possible exception of the use of additional relaying.

b. Three types of electrical power systems are utilized to supply the C4ISR facilities identified in paragraph 1-2. These vary in size and the type of equipment installed within as noted.

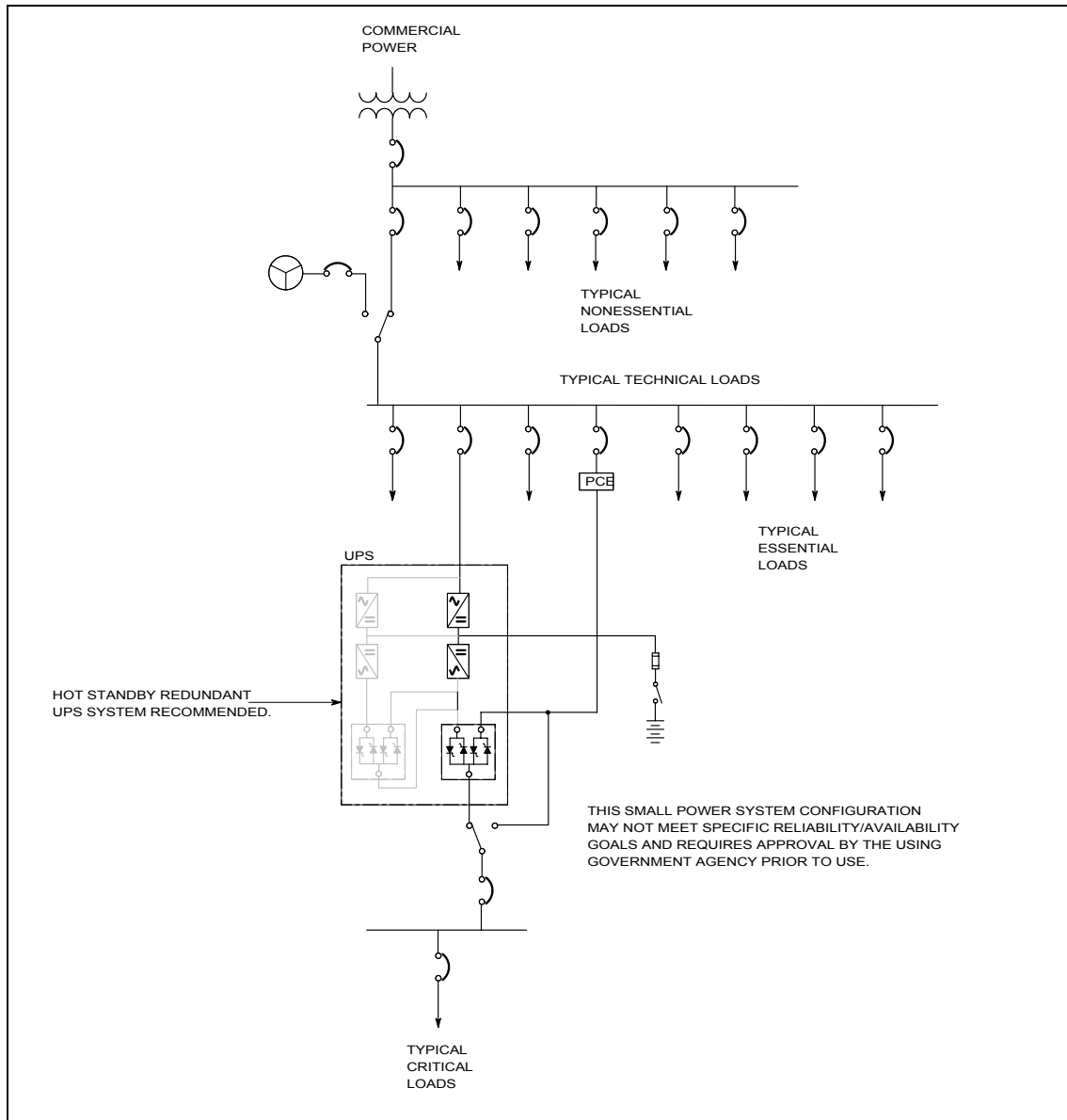


Figure 10-2. Small capacity power system

(1) The small capacity system (less than 250 kVA) is typically used to supply power to a remote data and/or telephone switch site. Such a system would generally utilize a service transformer supplied from one off-site power source and a single standby diesel or natural gas generator. Equipment inside would consist of a small rectifier for a 48 VDC bus, a small inverter, and several distribution panels. Note that because the small capacity system described herein may not meet the stringent reliability/availability (R/A) goals outlined elsewhere in this document, the AHJ should require a second standby generator for critical facilities. See figure 10-2 for a suggested configuration. The power conditioning equipment (PCE) shown in the figure may represent any number of methods commonly used to isolate critical loads from line disturbances, such as an isolation transformer, power conditioner, or motor-generator (MG) set. Use of a hot standby redundant UPS system (one in which the backup module is continuously energized and prepared to assume the critical load if the normally available UPS should fail) should also be considered.

TM 5-691

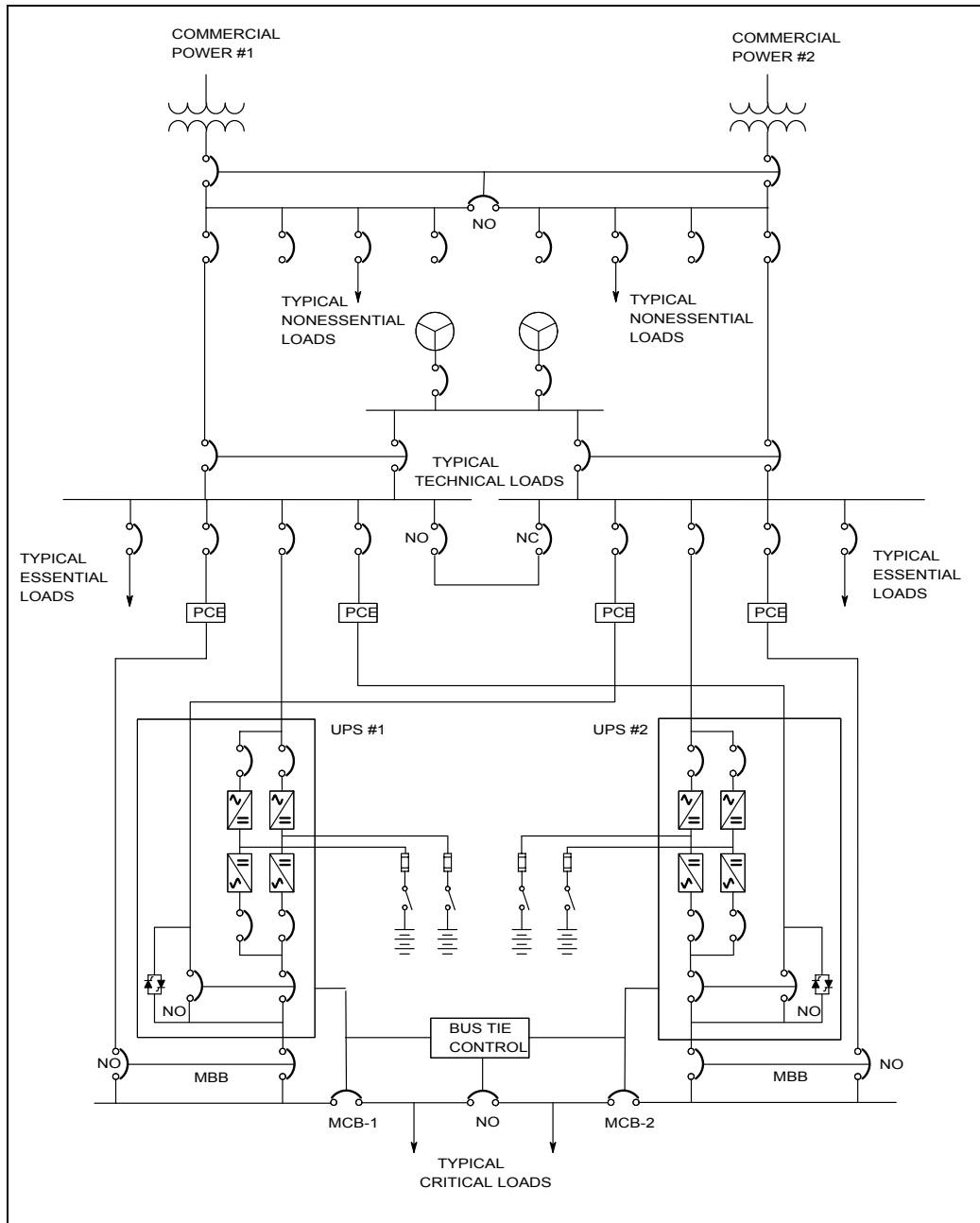


Figure 10-3. Medium capacity power system

(2) The medium capacity system (generally up to 2500 kVA) will support a main computer facility by utilizing one or two pad-mounted service transformers with primary selective feeders to the facility from the off-site power source. This system would utilize two low-voltage paralleled standby diesel generators, paralleling switchgear, and one or two large UPS systems. The main computer room would have numerous power distribution centers that supply conditioned power to the load. See figure 10-3 for a suggested configuration.

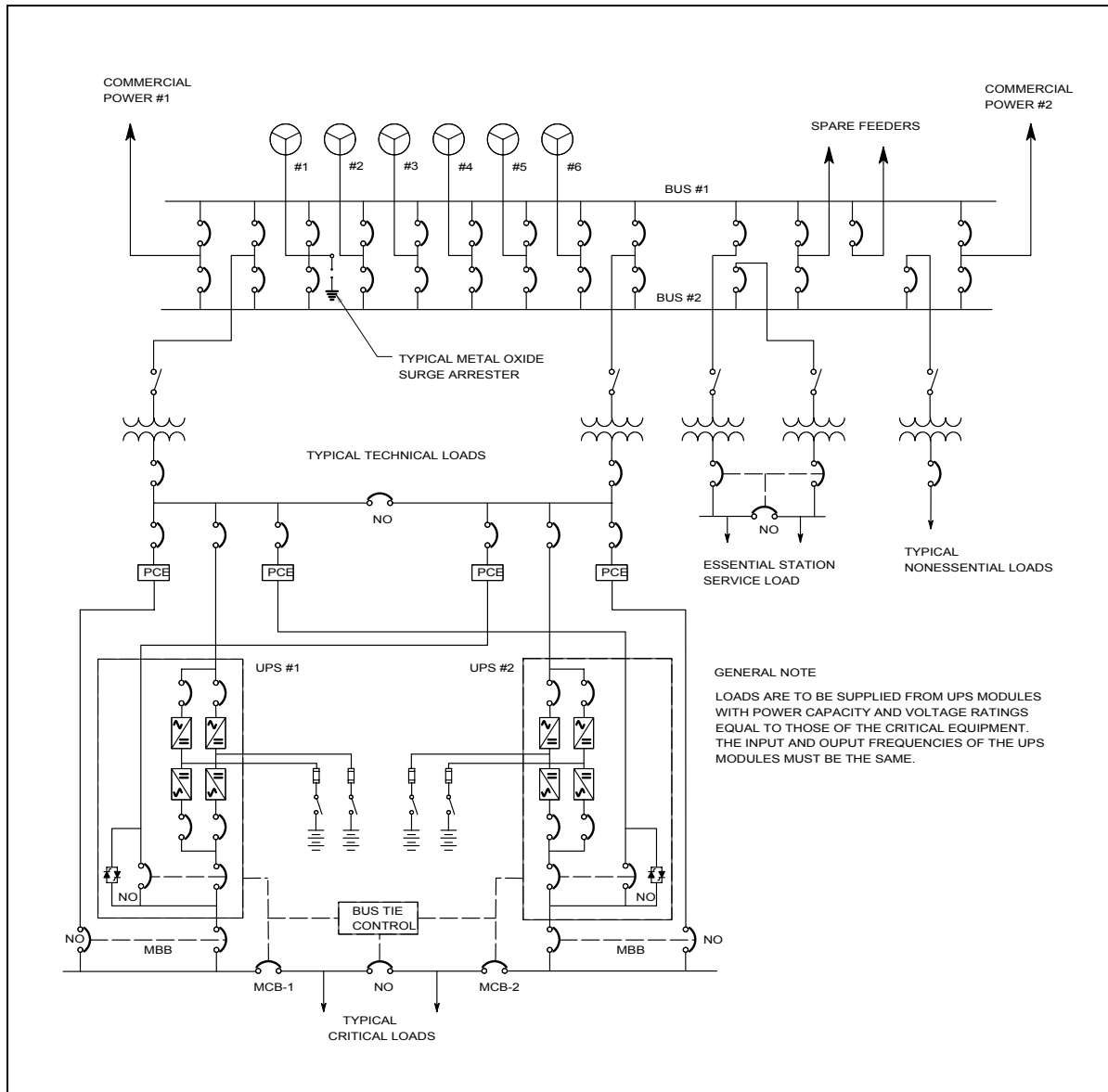


Figure 10-4. Large capacity power system

(3) A multi-facility site consisting of several installations will require a central power plant for supplying power to all of the buildings within the site. This large capacity power system (10 MVA or greater) will employ double-ended substations, paralleled medium voltage standby diesel generators, and large UPS systems. For example, the plant may contain five 2000 kW 4.16 kV (or 13.2 kV) diesel engine generators available for standby power. Each of the two transformers would be rated 5-10 MVA at 34.5 – 4.16 kV. See figure 10-4 for a suggested configuration.



**TM 5-691****10-2. Electrical systems maintenance**

The C4ISR power system shall be designed to facilitate maintenance. Preventive and routine maintenance will be performed by the operating crew without removal of components from their normal operating locations, except for equipment designed for removal and testing, such as power circuit breakers and protective relays. Support maintenance will be performed at an on-site maintenance facility by the site maintenance crew. During the off-site power mode of operation, off-site logistical and maintenance support is assumed to be available. During the on-site power mode of operation, only on-site logistical and maintenance support will be available. Corrective maintenance will be performed as necessary and with minimum impact on site operations. A minimum of a 30-day supply of site consumables, to be supplied by the using government agency, is required for on-site operation.

**10-3. Power quality**

Electrical loads at C4ISR sites may include extremely non-uniform and harmonic-producing equipment such as the transmitter for phased-array radar, UPSs, motors, IT and communications equipment. These loads can cause severe voltage wave form distortion and adversely affect generator set controls, protective relaying, and other connected equipment.

a. The site power distribution system shall comply with the table, "Standard Nominal System Voltage Ranges," presented in American National Standards Institute (ANSI) C84.1, Electrical Power Systems and Equipment – Voltage Ratings (60 Hertz). The commercial power service should meet and the on-site generated power shall meet the requirements of "Service Voltage" limits listed in ANSI C84.1. Site power distribution conductors shall limit voltage drops to values compatible with the "Utilization Voltage" limits listed in ANSI C84.1.

b. The design agency shall be required to show proper values for kilowatts, kilovolt amperes, and other variables related to frequency when the C4ISR site or project is to be served by a power source having a standard frequency different than 60 hertz.

c. A thorough analysis of the site loads, including load flow, transient motor starting, harmonic, and dynamic stability studies, shall be performed only for the large capacity systems employing multiple diesel generator units. Additionally, short circuit, coordination, and lightning protection studies shall be performed for both the small and large capacity power systems. Information and/or recommendations from the equipment suppliers must be obtained, and a variety of design techniques involving system configuration, generator set selection, and filtering of power and control circuits may be required. Use of power-conditioning equipment (PCE) shall be considered to minimize the risk of damage to critical loads resulting from the transients and unacceptable regulation common to utility power systems.

d. When it is determined from the electrical load analysis that the voltage total harmonic distortion (THD) will be greater than 5 percent, or that any individual frequency voltage harmonic will exceed 3 percent of the fundamental, the power system shall be stiffened. Use a separate neutral conductor for each branch circuit and minimize the use of shared neutral conductors. Evaluate the installation of an active harmonic filter. The following are acceptable methods for stiffening the power system.

(1) Increasing the transformer sizes

(2) Increasing the sizes of phase conductors and neutral conductors with neutral conductors being the larger.

(3) Adding additional transformers and conductors, limiting the length of conductors and using additional transformers with tap changing capability when the voltage drop is larger than that recommended by NEC.

(4) Redistributing loads to balance load currents (as well as harmonics in all phases of the three-phase system)

e. Equipment shall be ordered to Institute of Electrical and Electronics Engineers (IEEE) 519, IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems, specifications or to meet other relevant industry standards that limit the generation of harmonics. Loads that are sensitive to harmonics shall be isolated from those that produce harmonics by use of isolating transformers, motor-generator sets, or UPS. A periodic inspection, at least yearly and particularly after any change in system configuration is made, shall be conducted to assess harmonic-related problems.

f. The electrical power system shall be designed to enable the continuous on-line monitoring of electrical power to critical loads. Parameters monitored shall include voltage, current, frequency, harmonics, noise, and voltage transients.

g. Documentation of the systems design will be completed utilizing standard computer-aided drafting (CAD) procedures.

#### **10-4. Off-site electrical power**

Off-site commercial or utility power sources shall be used when available. Any commercial power source considered shall have an adequate quantity of power to supply the site operational load. For both large and medium capacity power systems, two separate commercial power sources are preferred to supply the C4ISR site primary substation(s). When two separate sources are not available, a single commercial power source should be used to supply redundant transmission lines to the site. The redundancy shall be provided through two or more full capacity circuits supplied from normally isolated switchgear buses in the power provider's substation. Small capacity power systems will generally be supplied by a single distribution feeder from the commercial power source. Design of the off-site power supply, the power distribution system, and the on-site generating power system shall permit scheduled outages for maintenance, repair, or testing of equipment or materials without significant impact on the C4ISR site missions. Independence and R/A of the off-site power source(s) shall be maximized through contractual arrangements with the commercial power company or companies. When off-site power is used exclusively, the on-site power supply shall be on standby. The availability of this mode shall be calculated.

a. A survey shall be conducted to determine the availability of commercial power sources in the vicinity (ten miles or less) of each new C4ISR site, and an evaluation shall be made with regard to past R/A history (power outage frequency, duration, etc.). The R/A history of each available source shall be a prime criterion in selecting the preferred line, which shall be rated not less than 15 kV. Use of two widely separated commercial power lines is recommended in preference to use of a single line, but the decision to use a second source, when available, shall be made on a site-specific basis by the using Government Agency. If two commercial power sources are used, the C4ISR site primary substations shall be located as far apart as practical, but reasonably close to the on-site power supply for the C4ISR site. TM 5-811-1, Electrical Power Supply and Distribution, chapter 1, contains design guidance for the primary substation.

b. The contract with any commercial power company shall be based on single-point, primary metering and shall allow for the paralleling of on-site generating units with the commercial power line or lines at the discretion of the C4ISR site operating contractor. The contract shall require the company to maintain

**TM 5-691**

power to the site continuously, regardless of other power demands on the transmission system. The contract shall also specify the maintenance responsibilities of the commercial power company. Recommended responsibilities of the commercial power company include regularly scheduled maintenance of commercially owned lines and equipment necessary to ensure continuous service.

c. Figure 10-5 shows typical equipment and relaying for a C4ISR site primary substation supplied by a single commercial power line, and should be referenced in relation to the following design guidance.

(1) Line switches designated as switches 1, 2, and 3 on figure 10-5 shall be the group- or gang-operated type of air switches for isolation of the line circuit breaker and for bypassing that breaker when it is out of service for maintenance. Consideration shall be given to the use of a fused bypass switch unit to protect the transformer against faults when the line circuit breaker (LCB) is out of service.

(2) Consideration shall be given to the use of SF6 type breakers. The use of the circuit-switcher type of protective device shall be approved by the using government agency or its technical representatives.

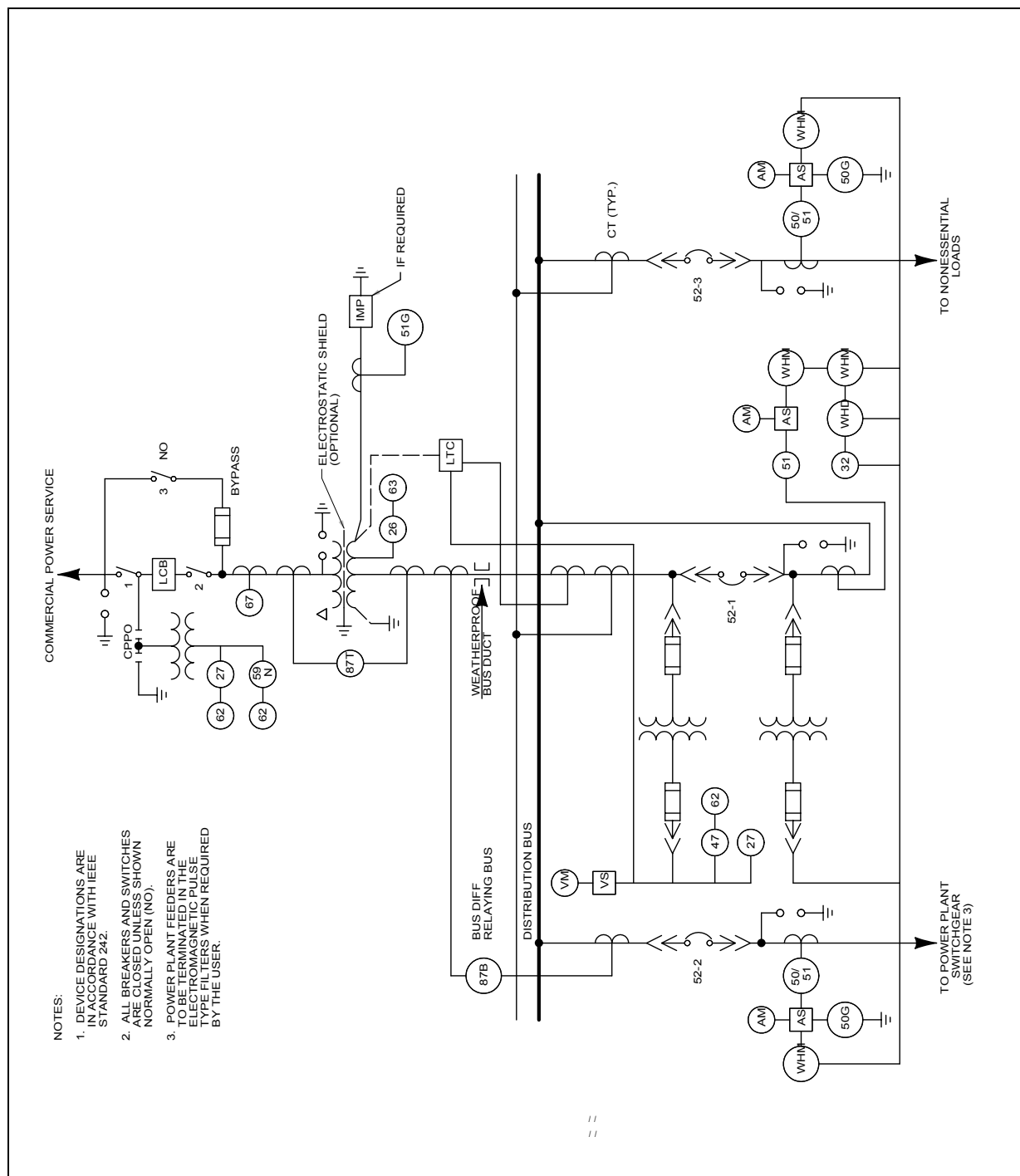


Figure 10-5. C4ISR site primary substation

(3) Power transformers installed at the primary substation shall comply with the following criteria.

(a) The voltage rating shall be consistent with the nominal voltage rating of the commercial power line and with the nominal voltage rating of the site power distribution system. The kilovolt ampere rating shall be sufficient to supply the peak demands of the C4ISR site technical facilities

**TM 5-691**

and any non-essential support facilities continuously without exceeding the 65°C (149°F) thermal rating in an ambient temperature typical to the site of installation. The transformer(s) shall contain delta primary windings and wye secondary windings with neutral connection tap provided for use as either a direct ground or a resistance ground connection. The transformer shall have provisions for the future addition of fans. If a double-ended substation is used, the kilovolt ampere rating may be reduced to 90 percent of the peak site demands, but the transformer shall be equipped with one stage of fans, with provisions for the future addition of a second stage of fans.

(b) Large power transformer(s) may be equipped with an automatic load tap changer (ALTC) to maintain adequate voltage regulation if the power system load profile and configuration so warrant. If two or more transformers are required or selected during design, the ALTC shall include cross-current compensation. The ALTC shall have sixteen 0.625 percent taps above and sixteen 0.625 percent taps below the nominal voltage rating of the secondary windings of the transformer. The ALTC control system shall have line drop compensation to account for the voltage drop along the transmission line(s) supplied by the power transformer. The controller shall have adjustable bandwidth (i.e., error limits) and setpoints, and an adjustable control voltage range (110-130 volts).

(c) The station class of metal oxide type arresters shall be installed at the high-voltage terminals of the transformer. The same type and class of arresters shall also be installed at the medium-voltage terminals of the transformers if aerial conductors are used to interconnect the transformer with the switchgear bus or buses.

(4) Circuit breakers shall be the vacuum type and shall be protected by the metal oxide type of surge arresters. Instruments, relays, and control devices shall be mounted on the front of the associated breaker or auxiliary units. Consideration shall be given to the proper ventilation or air conditioning of the metal-clad switchgear and to the installation of a spare circuit breaker equivalent to the breaker having the largest load rating.

(5) The relaying and control scheme shall make possible the clearing and isolation of faults and the separation of C4ISR technical loads from the commercial power source during faults or abnormal operating conditions on the commercial power line. A short circuit protection and coordination study shall be made by the design agency. The coordination study shall demonstrate that protective devices in the primary substation switchgear will properly coordinate with each other, with relaying used by the commercial power company, and with relays to be installed in the site's low- and medium-voltage switchgear assemblies.

**10-5. On-site power generation equipment**

To ensure an optimal degree of reliability of on-site generating units during actualization of threats, the commercial power source shall be utilized to an optimal extent during normal operating conditions at the C4ISR site. The characteristics and quantity of power to be supplied by on-site generating units will depend on the type of equipment (which is determined by mission requirements), the criticality of such equipment, and the different types of facilities or projects to be designed and constructed. Operational on-site units shall be capable of supplying the peak site demands while operating independently of any commercial power source when loaded between approximately 60 and 80 percent of their rated load capacities. Loading of active generating units shall not exceed these percentages. For large capacity power systems, the total number, "T", of on-site generating units required to supply the peak power demands and to ensure that the minimum availability goal is achieved shall be computed using the formula  $T = N + 2$ . "N" is the number of on-site generating units required to supply the peak power demands at between 60 and 80 percent of their rating and 2 is the required number of redundant units. (One unit is required for backup and one unit is required for maintenance outages.) For medium capacity

power systems, the formula  $T = N + 1$  shall be used. The long term and defined mission time reliability indices of the system shall be calculated for the on-site mode. The availability of the system for the off-site/on-site power mode shall also be calculated.

a. For on-site power generation, the power plant shall contain stationary prime mover generator sets and associated ancillary and control systems. TM 5-811-6, Electric Power Plant Design, contains design guidance for selecting sizes of generating units. Any generator supplying the minimum C4ISR facility demand shall be designed to be loaded to at least 50 percent of the kilowatt rating. The C4ISR on-site power plant for large capacity power systems shall be capable of making the transition from the off-site to the on-site power mode of operation in not more than three minutes, including starting and synchronizing a sufficient number of generator units to serve the technical load. Specific applications may require a shorter starting time, particularly for medium and small capacity systems or for generator(s) supplying life safety loads. On-site power units shall be capable of being started using only on-site equipment and facilities. All generators (including standby units) shall be continuous duty rated.

b. Generators shall be specified in accordance with ANSI C50.10, Rotating Electrical Machinery-Synchronous Machines, and National Electrical Manufacturers Association (NEMA) MG 1, Motors and Generators, standards as minimum requirements. The generator sets for large systems shall be capable of parallel operation with a commercial power source and with each other. The generator windings shall be three-phase, wye connected, with neutrals brought out for external connection.

(1) The generator voltage shall be the highest standard voltage commensurate with the load served and the electrical distribution system characteristics. NEMA standard voltages shall be used except where special conditions prevail. The frequency shall be 60 hertz unless the C4ISR site is located in an area where 60 hertz is not standard.

(2) The static type of exciter-voltage regulator shall be used for generator field excitation for all generators rated 1,000 kVA or larger. A static exciter-voltage regulator shall also be used for generators smaller than 1,000 kVA except when brushless exciters are customarily furnished with those sizes and deviation from the manufacturer's standard design would result in excessive costs. If brushless exciters are used, they shall be the series boost type.

(3) At any lagging power factor from 0.8 to 0.96 as the steady-state load increases from 0 to 100 percent of rated generator capacity, the exciter and regulator combination shall maintain voltage stability within the limits specified in paragraphs (a) and (b) below.

(a) The voltage variation at any steady-state load from 0 to 110 percent of the generator capacity shall be within 0.5 percent of the rated voltage. The term "steady-state variation" is defined in the glossary at the end of this manual.

(b) Transient voltages shall not exceed 5 percent after a 25 percent step change in load. The voltage shall recover to nominal voltage  $\pm 0.5$  percent within one-half second after initiation of the load change.

(4) The governor shall maintain a constant speed within  $\pm 0.25$  percent for any constant load between one-fourth and full load kilowatt rating of the generator. After any sudden load change of not more than 25 percent of the rated load, the transient speed deviation shall not exceed  $\pm 3.0$  percent, and the governor shall re-establish stable operating conditions in not more than three seconds.

c. The generator set control system for large capacity power systems shall permit use of both automatic and manual procedures for startup, synchronization, and loading to either switchgear bus. The

**TM 5-691**

automatic synchronizers, load-sharing and speed controls, and actuators shall be compatible with each other and with the automatic procedure, while manual speed and load control switches shall preserve the option of manual control. One synchroscope and associated "incoming" and "running" frequency and voltage meters, synchronizing lamps, and switches shall be provided for each of the two switchgear buses. The design shall also include a selector switch which will permit automatic or manual synchronizing of generators to either switchgear bus.

(1) A time control unit shall permit accurate timekeeping and serve as a frequency standard when the on-site generator sets are operating in isolation from the commercial power company. The time control unit shall have at least as many outputs as there are generating units in the plant. The time control unit shall automatically correct for cumulative time errors.

(2) The control system shall include an automatic load-sharing control system. Load trimmers or controllers shall be provided for elimination on inequalities in generator loads. The system shall smoothly adjust the load on an incoming unit to its proportional share of the total bus kilowatt load.

(3) A reactive differential compensator shall be provided for automatically equalizing the volt-amperes reactive (VARs) supplied by each on-site generator. The compensator shall include the voltage regulator for each generator and cross-current compensation current transformer which senses the phase currents of each operational generating unit.

(4) This unit shall control the inflow of power from the commercial power company to the on-site power plant switchgear buses. This power flow shall be held to a desired level either remotely by a signal converter in the control room (CR) or as set by a potentiometer located on the power plant switchgear. The power interchange control unit shall have high- and low-limit settings to prevent the generators from becoming overloaded or from being motored by the utility company.

(5) Provision shall be made for automatic flashing of generator fields at the time of generator set startup, using a power plant station battery as the dc power source. UPS batteries shall not be used for this purpose. If a static exciter is specified, the design shall show provisions for automatically disconnecting the field-flashing circuit when each "incoming" generator attains 90 percent of rated speed.

(6) Automatic sequence control equipment shall be provided to startup, synchronize, load or unload, adjust the reactive load of units, and to shut down units in the selected order.

d. For large generators (over 12.5 MVA) a low-voltage power circuit breaker, electrically operated under control of the generator set automatic sequencer and relays shown on Figure 10-6, shall provide the generator field protection. Fuses are typically used to provide field protection on smaller generating units.

e. Figure 10-6 illustrates a typical arrangement of generator protective relaying. IEEE 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, shall be used as a guide for design. Typical generator protection shall be provided for units rated 0-500 kVA above 5 kV, 500-1,000 kVA above 2.4 kV, and greater than 1,000 kVA regardless of the voltage rating. Protective devices shall respond to the true root mean square (RMS) value of current.



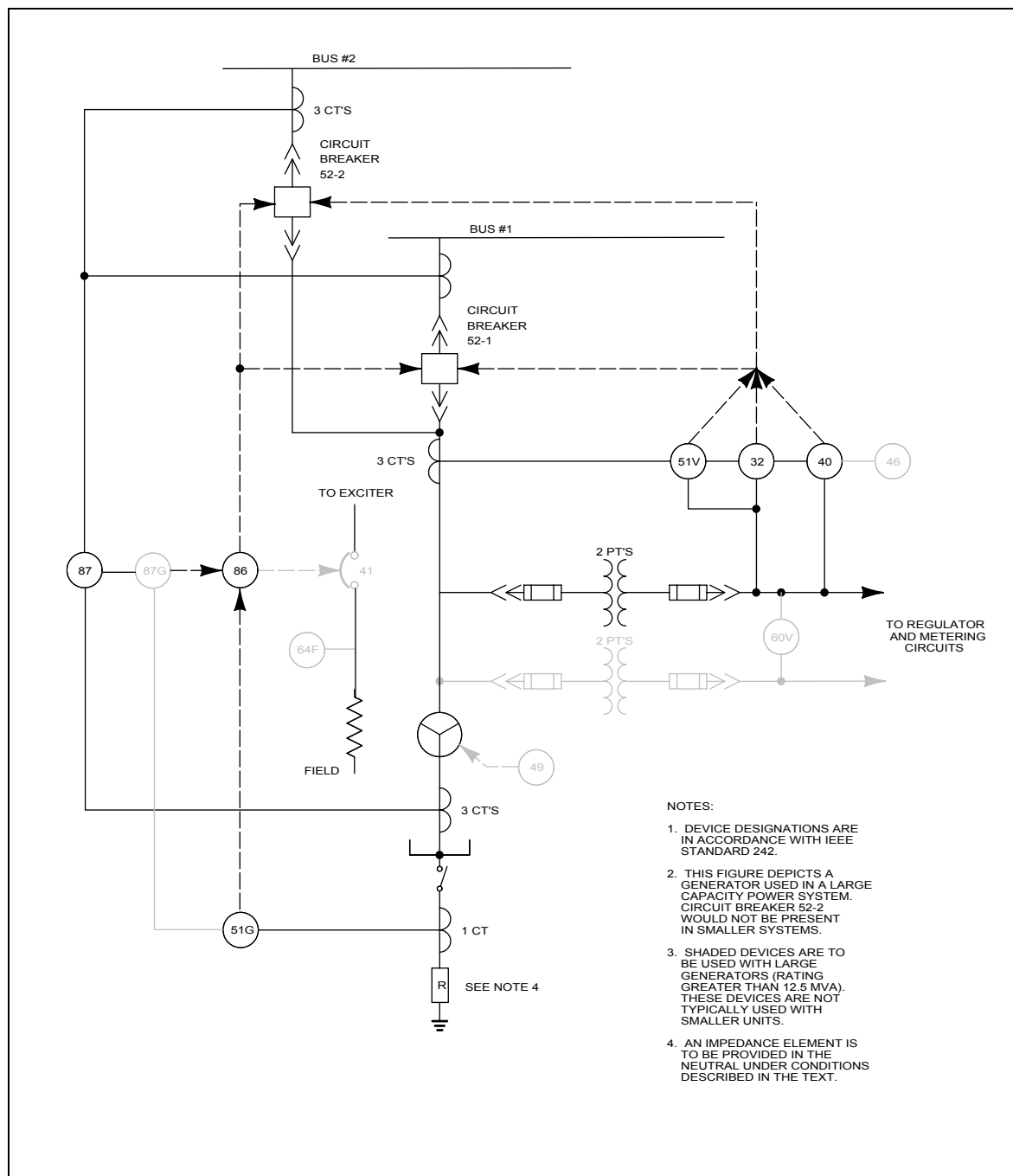


Figure 10-6. Generator protection system

f. Each generator shall be protected against damage from severe voltage transients caused by lightning or switching surges. IEEE 141, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants, states that the standard protective circuit for rotating machines consists of arresters and capacitors located near the machine terminals. The arrester's function is to limit the magnitude of the voltage to ground, while the capacitor decreases the rate of rise of voltage at the machine terminals. Surge arresters shall be connected between ground and each phase conductor, and shall be specified to be mounted on the line side of the circuit breaker as near the generator terminals as possible. The station



**TM 5-691**

class of metal-oxide type of surge arresters shall be specified. Vacuum pressure impregnated (VPI) generator windings shall also be specified.

g. Equipment associated with each generator, such as the generator exciter-regulator, neutral breaker, annunciator panels, instrument transformers, instruments, relays, synchronizing devices, and switches, shall be grouped near the generator in or on suitable switchgear enclosures. A remote annunciator panel indicating all alarms shown at the generator control panel shall be provided in an area with 24-hour occupancy. Generator switchgear shall have the ability to connect to an external mobile generator in the event of an emergency.

h. The neutral conductor of each generator shall be grounded either solidly or through an impedance element such as a resistor, reactor, or transformer. The type of grounding shall be determined based on the magnitude of the ground-fault current available from all sources. The rating of the impedance element selected and approved shall be sufficient to prevent damage to the generator and cabling due to ground fault current, but adequate to allow sufficient ground fault current to flow to cause the ground relay to operate and isolate the generator from the power system.

i. Load banks shall be specified if the system is unable to parallel and synchronize with the off-site power supply (typically the case for small and medium systems). Load banks shall have the capacities required to permit system testing of associated generators at approximately 50, 75, 100, and 110 percent of the kilowatt rating of the power plant. If possible, load banks shall be portable. Load banks shall permit testing at a minimum of two power factors. Power factors of 0.8 and 1.0 shall be included.

**10-6. Load shedding and restoration**

For large capacity power systems, a load-shedding and restoration scheme shall be designed for disconnecting essential and non-essential electrical loads when the capacity of the power source to supply these loads is curtailed or when power service is interrupted. The load-shedding and restoration programs shall provide automatic responses to the different operating conditions.

a. When the C4ISR facility is operating on commercial power only and the supply is interrupted, all loads except those served by Puss shall be de-energized and separated from their power sources. When commercial power is restored, or when on-site generators are operational and connected to the switchgear bus, the loads shall be reconnected in the order of their importance, based on the hierarchy of loads defined in figure 10-1.

b. When the C4ISR facility is operating on on-site power only, partial or total loss of all generators shall result in the partial or total shedding of essential and non-essential loads. If partial loss of generators occurs, loads shall be shed to match the remaining generator capacity until reserve generators can be put on line or the commercial power source can be re-established. In the event of total loss of on-site generating capacity, the commercial power supply, if available, shall be used to minimize the duration and extent of a non-operational condition. If a commercial power source is not available, on-site generating capacity shall be restored as soon as possible after the fault is detected and isolated. The restoration sequence shall be in the order of the load hierarchy defined in figure 10-1.

c. If during parallel operation between commercial power and on-site generators the on-site generators shut down, no load-shedding scheme is necessary. In the event of commercial power failure during parallel operation with on-site generators, the load shall be shed or trimmed automatically to match the capacity of the generators that are on the bus, using the hierarchy of loads defined in figure 10-1.

### 10-7. Exterior distribution system

Distribution feeders from the C4ISR site primary substation shall be installed in underground ducts whenever feasible. The voltage drop shall not exceed three percent. When the distance between the primary substation and C4ISR facilities makes a conventional underground system an unrealistic option, a feasibility study shall be made which includes a thorough analysis of comparative life-cycle costs and R/A for several options. Two options which shall be considered are: two or more aerial cables containing the three-phase and neutral conductors, and use of a distribution voltage higher than the nominal voltage rating of on-site generators used in conjunction with an exterior substation located at the site.

- a. Design requirements for the exterior distribution system shall be determined by the using Government agency after evaluating the result of the feasibility study discussed above. Design guidance for aerial and underground distribution systems is contained in TM 5-811-1, chapter 1, and shall be followed except as otherwise indicated. Distribution feeders shall be terminated at filters to afford protection against high-altitude electromagnetic pulse (HEMP). This requirement shall be considered in any feasibility study conducted.
- b. An underground distribution system shall be selected whenever feasible, and shall be installed in such a manner as to dissipate the currents that would be produced by EMP. The number of active feeders and the need for a spare feeder shall be considered based on the limitations in capacity of EMP power line filters, criticality of loads and mission requirements, and the consequent degree of R/A necessary to accomplish the missions successfully. Reliance on continuous or frequent operation of on-site generating units shall be at a minimum. Consideration shall be given to using two or more active feeders to serve separate power distribution switchgear buses under normal operating conditions. If two or more active feeders are to be installed between the primary substation and the C4ISR site, they shall be installed in separate ducts located a sufficient distance apart to prevent a single destructive event from causing physical damage to the two or more active feeders.
- c. An aerial distribution system shall be provided between the C4ISR site primary substation and a location near the point of entrance if a complete underground distribution system cannot be justified. To ensure that the R/A of the aerial system approximates that of the underground distribution system, the distribution circuits shall be designed to transmission line standards to protect the line or lines from the usual causes of outage to aerial distribution lines. Each end of the aerial circuits shall be equipped with the station class of metal oxide surge arresters, and automatic reclosing features shall be incorporated into the design. The routing of aerial distribution lines shall be selected to prevent a single destructive event from causing damage to the two or more distribution lines.
- d. Administrative and other types of non-essential support facilities shall be supplied power directly from the primary substation. However, the design shall permit those facilities to be supplied by on-site generators if needs so dictate. The choice of power source for these loads shall be made on an individual site basis. Protective fuses and relays shall be used to prevent tripping of the on-site power source or feeder breakers when faults occur on non-essential support facility feeders. Protective devices shall respond to the true RMS value of current.

### 10-8. Facility electrical distribution system

The facility electrical distribution system distributes power from the off-site power supply and the on-site generating units to the various operating loads and facilities at the C4ISR site.

**TM 5-691**

- a. Power system switchgear shall be arranged in a multiple bus configuration. For the large and medium capacity power systems, the two main switchgear assemblies shall be installed in separate rooms so that a fire or explosion cannot damage both assemblies. The switchgear shall contain an exterior connection for the deployable power generation and distribution system (DPGDS) to supply electrical power when requested.
- b. Breaker-interrupting capacity shall be adequate to interrupt the maximum symmetrical fault current available from incoming power lines, from the total number of generators, and from motors rated at or above 50 horsepower. Circuit breakers shall respond to the true RMS value of current.
- c. The application of protective relaying shall follow the guidance of IEEE 242. Generally, this specifies differential relaying for transformers 5 MVA and above, and for all generators except single isolated machines having very small kVA rating. Bus differential and frequency relays shall be provided for each switchgear assembly. They shall be properly coordinated with protective relays provided for the protection of the commercial power source(s), on-site generators, and interior distribution feeders; and with protective fuses, relays, or circuit breakers on the load side of the medium-voltage switchgear assemblies. Feeders that originate at the circuit breakers in the two switchgear assemblies shall be protected with high-speed ground fault and instantaneous and time-overcurrent relays as necessary to ensure proper coordination with the bus differential relays and related protective devices. A coordination study shall be done to verify coordination of protective devices in the power plant switchgear with protective devices "downstream" of the switchgear.
- d. For large capacity power systems, breaker pairs (see figure 10-4) common to the commercial power feeder(s) shall be used for synchronizing the on-site and off-site power sources. The breakers shall be rated to carry the total peak load currents and shall be electrically interlocked to prevent closure of both breakers unless bus one and bus two are synchronized. Breaker pairs common to the generators and those common to distribution feeders shall be electrically interlocked to prevent both breakers from being closed at the same time.
- e. Direct current power shall be supplied from the 125 volt station battery system. Figure 10-7 depicts a system which might be used for a large capacity power system. Station batteries shall be lead-acid flooded type. Separate dc station battery power circuits shall be provided for the functions associated with commercial power, generating units, and distribution feeders. Branch circuit protective devices shall be installed in each breaker cubicle, compartment, or unit to provide separate branch circuits for breaker close and trip and for breaker motor charging functions.

**10-9. Unit substations**

C4ISR facilities shall typically be supplied from indoor type, double-ended secondary unit substations, with the exception of small capacity systems, which shall typically consist of unit substations only. Figure 10-8 (from TM 5-811-1, chapter 1), shows the preferred arrangement for a double-ended substation. An independent power service to each of the substation incoming line sections shall be provided. The normal mode of operation shall be with the two transformer main secondary breakers closed and the tie breaker open. Interlocking shall be provided to prevent the bus-tie (BT) breaker from being closed unless one of the main breakers is open.

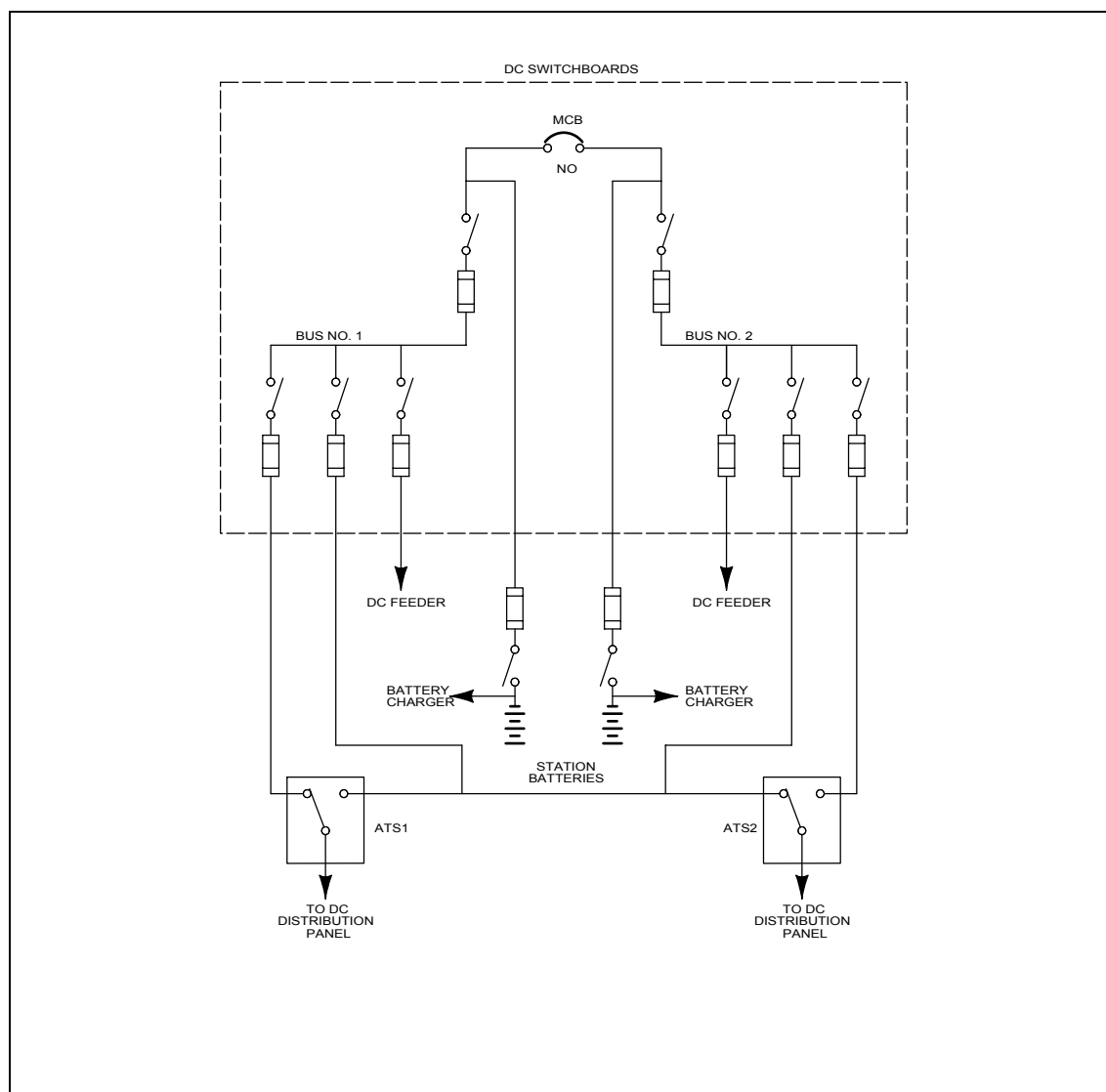


Figure 10-7. DC power distribution

a. Secondary transformers shall be non-ventilated dry type, or a sealed type. Secondary transformers shall be equipped with primary side surge arresters. Secondary transformers shall be equipped with a minimum of four 2.5 percent taps below and a minimum of two 2.5 percent taps above transformer nominal primary voltage rating unless otherwise indicated by the using government agency. Conventional transformers shall be derated, or K-factor rated transformers shall be used. The derating of transformers may be calculated by using either method given in IEEE C57.110, IEEE Recommended Practice for Establishing Transformer Capability When Supplying Non-Sinusoidal Load Currents. Derating methods that compare the crest factor of the load current to that of a purely sinusoidal waveform may underestimate the effects of higher order harmonics and shall not be used. Isolating transformers shall be used for supplying computer rooms and other non-linear loads and shall be K-rated. The recommended type is a power distribution unit (PDU) consisting of a delta-grounded wye isolation transformer and circuit breaker panels. Dry type transformers used to supply non-linear loads shall have impedance below six percent, preferably in the range of three to five percent as calculated at the nominal frequency. Three-legged core construction shall be used. Transformers serving computer and electronic

TM 5-691

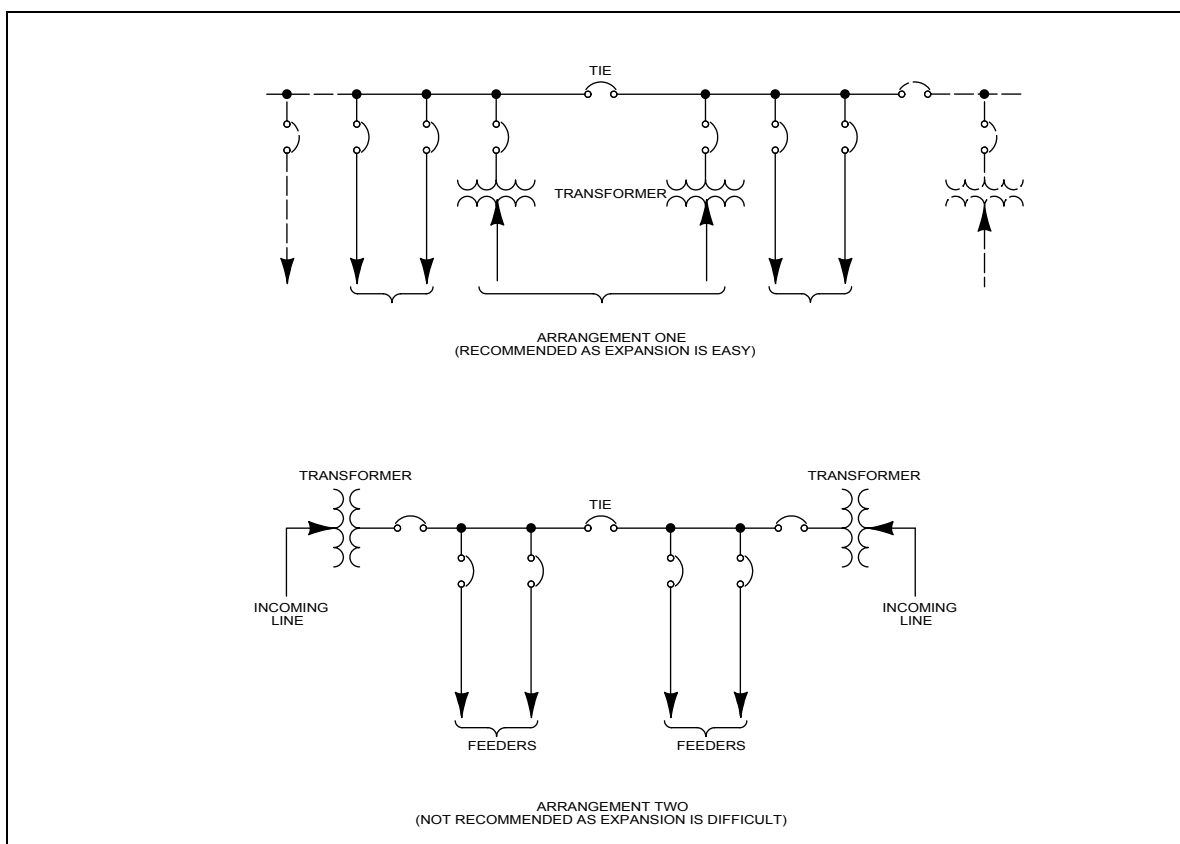


Figure 10-8. Double ended substation

loads shall be installed as close to the load as possible. Transformer-winding temperature sensors shall be provided and an over-temperature condition shall trigger local and remote visual and audible alarm signals.

b. Switchboards shall be equipped with an equipment grounding conductor, bus-bar system. For 120/208 volt switchgears supplying load feeders, the neutral conductors shall have an ampacity greater than 2 times the ampacity of the individual phase conductors.

c. Main and tie circuit breakers shall be the electrically operated drawout type. Feeder circuit breakers shall be the electrically operated drawout type when load demands exceed 225 amperes and feeders serve critical or essential loads. All breakers shall incorporate solid-state adjustable trip control elements. The main breakers shall be equipped with undervoltage trip devices having static time delay units. Local and remote indicating lights shall continuously indicate the open or closed status of each breaker. Automatic tripping of breakers shall be annunciated at the substation and in the CR. Circuit breakers shall respond to the true RMS value of current.

d. If the substation is designed with common neutral conductors and a ground point at each transformer, either a modified differential scheme or a summation relaying scheme shall be used.

e. Unit substation main busses shall be provided with electronic power monitoring units. Functions provided shall include voltage, current, kilowatts, kilovars, kilowatt-hours, harmonics, etc. Units shall be capable of storing function data.

#### **10-10. Motor control centers and distribution panels**

Motor control centers, power distribution panels, and lighting distribution panels shall be provided with redundant breakers and buses and a bus-tie breaker when they serve critical loads required for maintaining operations under adverse circumstances. Under such circumstances, associated feeders shall be provided; these feeders, in conjunction with electrically operated circuit breakers, shall permit critical or essential functions to be performed to operate the C4ISR technical facilities properly. The primary feeder to each motor control center, power distribution panel, and lighting distribution panels shall originate from different unit substation buses. Non-linear loads shall be supplied from heavy-duty panelboards. For these panelboards, minimum line bus bar ampacity shall be based on full load plus 25 percent. The ampacity of the neutral bus-bar assembly shall be no less than two times the ampacity of the largest ampacity phase assembly. Panelboards serving computer and sensitive electronic loads shall be installed as close to the load as possible. Protective devices shall respond to the true RMS value of current.

#### **10-11. Automatic transfer switches**

Automatic transfer switches and associated bypass switches will typically be used in small capacity power systems. In general, transfer switches shall be of the electrically operated, mechanically held type, designed to provide automatic transfer of load from the normal power source to the alternate power source and to return the load to the normal power source on restoration of power. Transfer switches shall be of the double-throw type operated by a momentarily energized coil or motor mechanism and shall be positively locked on either source of power. Transfer switches shall be three pole except in systems using neutral switching. Four pole transfer switches shall be used where neutral switching is required (see paragraph 10-16.e.).

#### **10-12. Interior distribution systems**

Redundant feeders or branch circuit cables shall provide power to critical and essential loads and shall be contained in separate cable trays, conduits, or raceways routed along separate paths sufficiently remote from each other to prevent a single destructive event from damaging both power sources. Consideration shall be given to fireproofing cables in trays in areas where fires are likely to occur if routing through such areas cannot be avoided. TM 5-811-2, chapter 2, Electrical Design, Interior Electrical Systems, contains design guidance and guide specifications for interior distribution systems and other interior electrical work. The design agency shall specify separate feeders and branch circuits for computer and sensitive electronic loads. Loads that are sensitive to harmonics shall be isolated from those that produce harmonics. Isolation methods include transformers (including single-phase transformers serving single-phase loads), motor-generator sets, UPS, and power-line conditioners. A separate neutral shall be run to 120 volt outlet receptacles on each phase. Sharing of a neutral conductor for single-phase 120 volt outlets on different phases shall not be permitted. Protective devices shall respond to the true RMS value of current.

#### **10-13. Lighting and receptacle systems**

The design of the general lighting system shall be based on energy conservation. Circuiting shall be provided to prevent inadequate illumination in an area should a branch lighting circuit breaker operate to de-energize the lighting circuit.

**TM 5-691**

a. Basic types and sizes of fixtures which can adequately illuminate the facility shall be specified for shop areas and general exterior and office environments of the facility. A standard set of fixtures for each of the major lighting types (fluorescent, incandescent, and high-intensity discharge) shall be specified.

b. Emergency lighting fixtures shall be located in the mission areas and where needed to adequately illuminate areas and equipment to be used to restore power following a complete electrical power outage in the C4ISR technical and technical support facilities. This system shall be in addition to conventional exit lighting. Locations housing emergency generators shall be provided with battery-powered emergency lighting. The emergency lighting charging system and the normal generator room lighting shall be supplied from the load side of the transfer switch. Both emergency and exit lighting fixtures shall be supplied from battery systems separate from the UPS batteries.

c. The illumination level throughout the CR shall not be less than 50 foot candles, except near cathode ray tube (CRT) type of equipment and near control panels where excessive glare would be detrimental to the visual acuity necessary under emergency conditions. Control panels or consoles shall be provided with canopies having integral lighting fixtures and dimmers necessary to obtain the proper level of illumination. General illumination levels near CRT type of equipment shall range between 15 and 25 foot candles, and shall be variable through the use of dimmers or dimming ballasts and controls.

d. Battery room lighting fixtures shall be vapor-proof and acid-resistant.

e. Receptacles of the proper type and rating shall be located throughout the C4ISR technical and technical support facilities as needed to facilitate operation and maintenance activities under normal and abnormal conditions. Receptacles necessary for operation under abnormal conditions shall be supplied from the UPS. Welding receptacles shall not be connected to the UPS.

**10-14. Direct current systems**

The dc system shall consist of separate batteries, switchboards, automatic transfer switches, and associated equipment similar to the UPS system equipment. Separate battery systems shall be provided to supply DC power to control circuits, exit and emergency lighting, and generator exciters.

a. The battery shall be rated for at least 125 percent of the peak load demand. Wet cells are generally preferred due to their longer life and the absence of the thermal runaway problem present with valve-regulated lead acid batteries.

b. The battery charger rating shall be consistent with the battery rating. The battery charger shall be supplied via a redundant pair of full-capacity feeders originating at the technical utility buses, and shall be switchable between the two sources. Non-liquid type batteries shall be equipped with cyclic chargers.

c. An adequately rated thermal-magnetic breaker or a fused load-break switch shall be provided at each battery to protect the battery output feeders. The breaker or fuse shall be rated to trip at battery full-load current. The time-current characteristics of the protective device selected shall be properly coordinated with other protective devices in the associated circuits.

d. A normally open, non-automatic type of circuit breaker or non-fused disconnect switch shall be installed in one of the dc switchboards to serve as a maintenance circuit breaker (MCB).

e. All switches shall be fused with dual-element, current-limiting type fuses. Peak let-through energy shall be coordinated with the fault current withstand ratings and the overcurrent ratings of the associated



switches. Fuse ratings of the branch circuit switches in the inverter circuits shall be coordinated with the current inrush characteristics of the inverters. Fuses in the incoming lines from the batteries shall be coordinated with the short-circuit ratings of the batteries.

f. Instrumentation in the distribution switchboards shall include voltage sensors that initiate local and remote warning signals when the switchboard voltage exceeds the nominal equalizing charge voltage or when bus voltage drops to less than 90 percent of nominal.

#### **10-15. Uninterruptible power supply (UPS) systems**

An UPS system designed to provide continuous on-line high-quality power without excessive voltage or frequency transients shall be installed to serve as the power source for critical loads. The reliability and availability requirement of paragraph 2-4 shall be used as the electric power availability requirement (EPAR) for power at the technical load buses that supply critical loads. The same EPAR shall be established for critical support and essential loads when the characteristics of such loads are compatible with the critical loads. A separate UPS system shall be provided for critical support and essential loads if they are incompatible with critical loads because of different frequency or voltage ratings, excessive capacity, or operational characteristics and transient effects during starting and stopping operations. In such instances, the headquarters of the using government agency is authorized to establish a lower EPAR or electric power availability goal (EPAG) consistent with the degree of availability required to ensure continuous and successful completion of the site mission. Provisions shall be made during design to permit an increase, with a minimum of cost, in the capacity of the UPS systems should load increase substantially in the future.

a. The UPS system shall be fully redundant. It shall contain dual inputs, dual modules, and dual outputs. Figures 10-2 and 10-3 show a parallel-supplied redundant type of configuration that allows compatible loads served through the UPS buses to be continuously supplied following a failure of either one of the modules. The cold standby redundant (CSR) type of UPS system shall not be used.

(1) The UPS system herein described is required for the medium and large capacity power systems where a ventilated battery room is required. The smaller capacity (less than 250 kVA) power system may require only a system prepackaged by the manufacturer.

(2) The UPS system shall be an insulated gate bipolar transistor (IGBT) pulse width modulated (PWM) switching type unless the kVA size dictates a silicon-controlled rectifier (SCR) type unit.

b. Consideration shall be given to the use of such power-conditioning equipment (PCE) in lieu of using a UPS system when the purpose of that system is to minimize the effects of excessive transients known to exist on the utility power buses. The design agency shall consider these and other available types and incorporate the proper type into the design as warranted by design requirements for specific sites and projects. Installation of PCE in the input circuit to the automatic and manual maintenance bypass circuits shall be avoided.

c. The overvoltage and undervoltage curves of figure 10-9 (taken from IEEE 446, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications) shall represent the boundaries to the ac output voltage of the UPS system. The power quality and performance specifications given in IEEE 446 shall apply as minimum requirements for the UPS system unless the data-processing equipment in the CR has conflicting requirements, or unless more stringent requirements are specified by the using government agency.



**TM 5-691**

d. The UPS system shall be compatible with the loads to be supplied by the individual or multiple module systems. Modules shall contain self-protection features for protection from abnormal operating conditions on the input and output buses and of internal components. The starting and stopping, loading, and unloading characteristics of equipment to be supplied by the UPS inverters shall be compatible with the UPS inverter modules. The use of reduced-voltage starters shall be considered for motors with ratings and load characteristics that would cause the opening of the UPS output circuit breaker or the automatic transfer to the bypass mode of operation if full-voltage starters were used. UPS features that afford adequate protection against severe frequency and voltage transients on the input and output buses shall be specified in the procurement specifications.

e. UPS equipment rooms are required for medium and large capacity power systems and shall be located as close as possible to their associated battery rooms, adjacent to them whenever practical. Space or other constraints may necessitate locating switchgear, motor control centers, and panelboards remote from the UPS equipment rooms. In these instances, such equipment shall be located as close as possible to the UPS equipment room. When sufficient space is available, the UPS output switchgear shall be contained in the UPS equipment room. Any motor control centers and critical load distribution panelboards shall be located in the same room whenever space can be made available to accommodate the equipment. Consideration shall be given to housing the UPS input and output switchgear, any UPS output motor control centers, and the distribution panels or panelboards for critical loads in the UPS equipment rooms. Consideration also shall be given to combining the input switchgear with the generator bus switchgear when the generator voltage is the same as the input voltage to the UPS modules.

f. Each UPS converter or rectifier/charger shall be solid-state. It shall have sufficient capacity to supply the full rated load current to the inverter while simultaneously recharging a fully-discharged battery to 95 percent of rated ampere-hour capacity within ten times the discharge time after normal ac power is restored. The quality of the converter output shall be adequate to serve as acceptable inverter input with or without a connected battery as long as ac input voltage to the power supply unit stays within the limits specified in ANSI C84.1 and the input frequency is 60 hertz  $\pm 0.5$  hertz. The ac input circuit breaker shall open and initiate local and remote alarm signals when there is an internal failure in the converter or when the battery has supplied current to the inverter for five minutes or more. If an internal exhaust fan is required for converter cooling, a redundant full-capacity fan shall be provided, and each fan's power supply circuit shall have independent overcurrent protection. The converter shall be interlocked with the battery room ventilation control system to prevent the converter from operating without proper ventilation.

g. Inverters shall be solid-state unless otherwise approved and shall be capable of accepting the output of the converter or battery and supplying the critical bus voltage and frequency. The inverter shall be capable of supplying an inrush current of seven times rated output current without damage or mis-operation. The inverter output frequency shall be "slaved" to the normal input frequency of the UPS converter. At other times, the inverter frequency shall be controlled by an internal crystal standard. The voltage variation at any steady-state load from 0 to 100 percent of the inverter capacity shall be within 0.5 percent of the rated voltage. The inverter shall be modularized. Semiconductor surge protectors shall be provided for the SCRs. The inverter shall have adjustable automatic limiting of current output. Performance specifications for inverters shall not be less than those given in IEEE 446. The inverter shall have the capability of compensating for output voltage when subjected to decaying battery voltage. If the output voltage cannot be properly regulated, then the inverter shall shut down. The inverter shall be equipped with self-protection against damage from an undervoltage on the input. More stringent requirements may be specified if warranted by the using government agency.

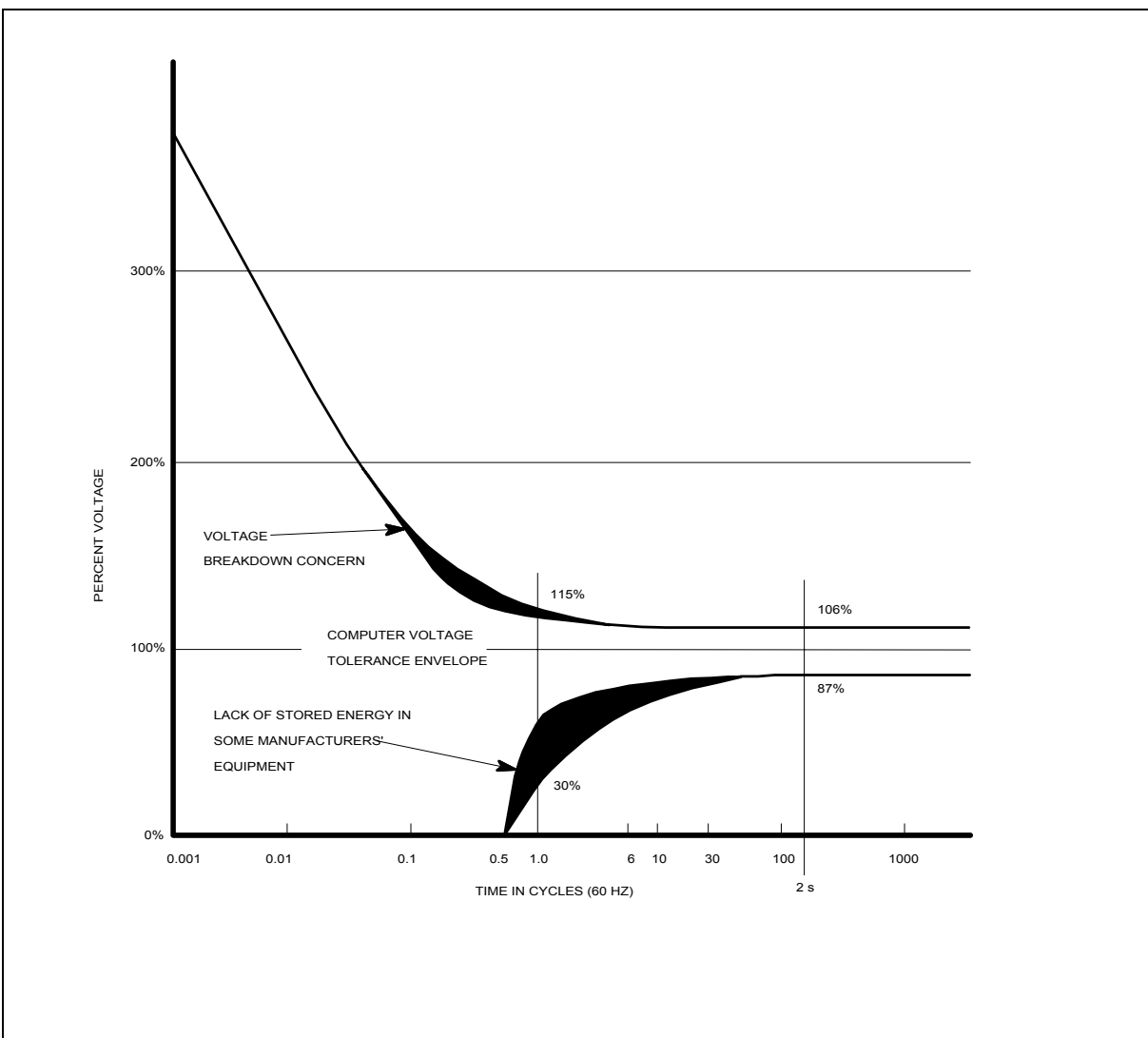


Figure 10-9. Typical design goals of power-conscious computer manufacturers  
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h. UPS switches of the static interrupter type shall be utilized unless the manufacturer's standard product incorporates the use of circuit breakers necessary for protection and isolation purposes. These breakers or switches shall be controlled by logic circuits in the UPS inverters or by other circuits included in a common control cabinet or panel. Signals so derived shall also cause closing of the static transfer switch when the monitoring circuits sense the failure of the inverter output or when the UPS module is driven into the "current limit" mode of operation for a preset period of time. Static transfer switches (STS) shall be specified to have control, interlocking, or logic circuits as needed to permit or prevent their closure as dictated by the operating mode of the UPS system. The speed of switching shall be such as to minimize transients on the UPS output bus and limit such transients within the frequency and voltage tolerances specified for the output of the UPS modules. In general, the static transfer switches should be specified to have a switching speed of five milliseconds or less. A switching speed of two milliseconds is obtainable in standard products of major manufacturers of UPS equipment and may be specified if consistent with the transient response time of the critical or essential loads.

**TM 5-691**

i. The maintenance bypass switches or breakers shall be specified to have a make-before-break feature when such feature is required by the standard design of the UPS manufacturer. Logic or interlock circuits shall be provided as necessary to prevent switches from being closed when the buses that supply the module, static transfer switch, and maintenance bypass switch are not synchronous. Maintenance bypass switches shall be the electrically operated type and shall have provisions for manual operation and locking in both operating positions. In medium and large systems the tie control scheme shall allow momentary and continuous operation of the tie between the load side of two UPS as shown in figures 10-2 and 10-3. Continuous operation will allow all critical loads to be placed on one UPS so the other UPS can be serviced.

j. The ampere-hour capacity of the station service battery systems shall be based on an eight-hour discharge rate. The ampere-hour capacity of the UPS battery system shall be based on a 15-minute rate or duty-cycle. The capacity of the batteries shall be increased as necessary to suit load growth by the future addition of new equipment or new mission requirements. The UPS design shall be flexible enough to permit one battery bank to serve as an active source of power to one UPS module and as a standby source of power to the other module. One battery bank shall be supplied for each module in a parallel-supplied redundant UPS system. Breakers shall be provided at the UPS modules if required for safety or for operational considerations. The design agency shall consider the recommendations of the UPS system equipment manufacturer in this and other regards prior to completion of the design.

(1) The cell type batteries supplied shall be lead-acid, flooded type (wet cell).

(2) Ampere-hour capacity of the UPS batteries shall be calculated by plotting estimated battery load current for the 15-minute duty-cycle against time, showing a continuous 15-minute load. Adequacy of the battery selected shall be verified by starting the calculations at the beginning of the discharge cycle and subtracting the ampere-hour energy removed by each load increment to determine whether enough capacity remains for the final load increment. Battery voltage at the end of the duty-cycle shall not be less than indicated in IEEE 446, unless the UPS manufacturer stipulates a different voltage.

(3) A 25 percent derating factor shall be applied to provide for the normal decline in battery capacity due to aging of plates. In addition, a derating factor recommended by the battery manufacturer shall be applied, as applicable, to compensate for reduction in battery capacity that occurs when the ambient temperature in the battery room is less than 25°C (77°F). For temperatures above 25°C the resulting increase in available capacity will be treated as part of the overall design margin, as recommended in IEEE 485, IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications.

(4) The battery rack shall be designed for compatibility with the seismic environment in which it is located, and shall be appropriately finished to resist corrosion by battery chemicals.

(5) The station service and UPS batteries shall be isolated in separate battery rooms which shall be ventilated in accordance with chapter 7. The ventilation system shall include sensors for initiating alarm signals to a central alarm station in the event of ventilation system failure. Reference paragraph 10-13 for type of lighting fixtures to be considered for the battery room. Location of the UPS battery room or rooms will be adjacent to the UPS equipment room or as close as feasible to that room. The station battery room shall be located in a central location to supply the station service loads.

k. Alarm, control, instrumentation, battery status, and UPS status shall be provided in the CR. Each of the UPS modules shall have indicating lights or other means of clearly indicating the on/off status of each converter and inverter, and the status of each static transfer and UPS switch and maintenance bypass circuit. Indication of component status shall be provided in the CR for each UPS. The ac to dc converter

unit shall incorporate meters both locally and at the CR for input voltage, input current, and output voltage, and an ammeter with zero at midscale for indication of charging or discharging modes of operation. The inverter assembly shall include meters for output voltage, output current, and frequency both locally and at the CR. All meters displaying electrical measurements in RMS values shall read true RMS values.

#### **10-16. Grounding system**

Grounding systems for conventional installations, including commercial power lines and substations, are specified in TM 5-811-1, Electrical Power Supply and Distribution, and TM 5-811-2, Electrical Design Interior Electrical Systems. Proper grounding methods for the safe and satisfactory operation of power, data processing (electronic equipment), and communication systems is also discussed in MIL-HDBK-419A, Grounding, Bonding, and Shielding for Electronic Equipment and Facilities. All metallic objects such as enclosures, raceway/conduits, equipment grounding conductors, and all earth-grounding electrodes shall be solidly bonded together with a continuous electrically conductive system. The metallic systems, such as the cold water piping system and the structural building steel system also shall be solidly interconnected to the service entrance electrical system. The grounding design and installation shall conform to all applicable codes and standards. These include NFPA-70, National Electrical Code (NEC); IEEE 142, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems; IEEE 1100, IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment; and Federal Information Processing Standards (FIPS) Pub 94, Guideline of Electrical Power for ADP Installations.

a. C4ISR facilities shall have an external grounding system, including a grid-type earth ground to be a part of a unified ground system. All exterior metallic components which penetrate the building, such as metal piping, conduits, and ducts, shall be grounded at the point of penetration. This system shall serve to ground all ordinarily grounded systems, such as generator and transformer neutrals or neutral impedance devices, electrical equipment enclosures, conductor shields, and the lightning protection system. The maximum resistance to ground of this system shall be ten ohms.

b. Each electrical room within the C4ISR facility which contains electrical equipment shall be provided with a ground bus, which shall be connected to the unified ground system.

c. AC power distribution systems shall have the neutral conductor grounded at the distribution transformer and to the earth electrode subsystem of the facility. The size of the ground conductor from the first service disconnect means to the earth electrode subsystem shall be as specified in Table 250-94 of the NEC. In each facility served by a common distribution transformer, the neutral shall be directly connected to the nearest point of the earth electrode subsystem. Where delta-wye systems conversion is employed, the service entrance shall be a five-wire system consisting of three phases, a ground (green) conductor, and a neutral. In each facility, all power distribution neutrals shall be isolated from the equipment case and the structure elements. The fault protection subsystem grounding (green) conductor shall be installed in accordance with table 250-95 of the NEC for all equipment. Conduit shall not be used as a grounding conductor.

d. The power system grounding shall ensure that all non-current carrying metal parts will be at the same ground potential, and that a low-impedance path is provided for fault currents. The selection of a grounding system shall be based upon magnitude of fault current, transient voltages, lightning protection, and application of protective relays for selective ground fault protection. Table 10-1 shall be used as a guide for power system neutral grounding applications.

(1) Grounding of electrical power circuits shall follow conventional practices except as follows.

## TM 5-691

(a) The insulated neutral cables from the commercial power substation, from the distribution transformer neutral or neutral impedance devices, and from each generator neutral or neutral grounding device, shall connect to a single ground location at the point of entrance of commercial power circuits into the utility equipment vault.

(b) Each neutral service shall have only one connection to ground. The connection shall be made at the origin of the neutral service. In double-ended substations, the transformer neutral or any transformer neutral grounding device shall be connected to a common insulated neutral bus, and the bus shall be connected to the grounding system at only one common ground point in the building grounding system.

Table 10-1. System grounding sub-application

System Voltage and Loads	POWER SYSTEM NEUTRAL GROUNDING			ELECTRONIC AND COMMUNICATIONS EQUIPMENT GROUNDING		
	Solid Grounding	Low-Resistance Grounding	High-Resistance Grounding	Single-Point Grounding	Isolated/ Insulated Grounding	HF Ground (Multi-Point)
A. 600 V and Below						
1. Linear Loads	X		X <sup>1</sup>	X		
2. Non-Linear Loads						
a. Data Processing	X					X
b. Process Controllers	X			X		
c. Adjustable Speed Drives	X			X		
d. Healthcare Facilities					X	
e. Communications						X
B. 2,400 V - 15,000 V						
1. Linear Loads	X <sup>3</sup>	X <sup>2</sup>	X <sup>3</sup>			
2. Non-Linear Loads						
a. Adjustable Speed Drives	X					
b. Converters/ Rectifiers	X					

<sup>1</sup>Used where high reliability is required.

<sup>2</sup>Used where majority of loads are three-phase motors.

<sup>3</sup>Used where there are single- and three-phase loads.

(2) Electrical power systems that are used to supply phase-to-neutral loads shall be solidly grounded. The maximum ground electrode impedance value for different facilities, as listed in table 10-2, shall be used for the design of solidly grounded systems.

(3) Electric power systems that are used to supply three-phase loads will be low-resistance grounded. The resistance value shall be chosen to provide a ground fault current acceptable for relaying purposes.

Table 10-2. Ground electrode impedance applications

FACILITY	MAXIMUM IMPEDANCE
General Industrial	5 ohms
Chemical	3 ohms
Computer Data Processing	Less than 3 ohms
Small Substation (local distribution)	5 ohms
Large Substation (regional distribution)	1 ohm
Generating Station	1 ohm
Commercial such as Metallic Building, Homes	Less than 25 ohms

(4) The high-resistance grounded system shall be used when high reliability is required. The application of high-resistance grounding to low voltage power systems shall be limited to three-phase systems of 480 to 1000 volts where ac line-to-neutral loads are not served. Ground detectors shall be installed on all high-resistance grounded systems.

e. Where ground fault protection is provided on the normal source distribution system, and the system has interconnected neutrals with an emergency/standby system, the electrical system design should include consideration of the use of four-pole transfer switches and grounding the emergency/standby source as a separately-derived system. Without the use of four-pole transfer equipment there may be sensing problems with the ground fault protection circuitry and the possibility of nuisance tripping. Generally speaking, whenever a sensing function for ground fault current is required on either source, four-pole transfer switches should be specified. To accomplish a separately-derived ground system, the connection shall be made between the emergency/standby source using an insulated copper cable and connecting directly to the earth ground grid.

f. Grounding practices for electronic and communications equipment shall be in accordance with IEEE 1100, IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment. A signal reference subsystem shall be installed at each facility. Where units are distributed throughout the facility, the signal reference ground subsystem shall consist of an equipotential ground plane. Table 10-2 shall be used as a guide for electronic and communications equipment grounding applications. See paragraph 10-19 for grounding associated with electromagnetic interference/radio frequency interference (EMI/RFI) shielding practices.

(1) A low-frequency system shall be installed at facilities employing low-frequency signals and shall be isolated from all other ground systems including structural, safety, lightning, and power grounds. It shall be connected to the earth electrode subsystem at one point only (single point) and configured to minimize conductor path length.

(2) A high-frequency system requires an equipotential ground plane. The equipotential plane shall be installed under the equipment. Signal, control, and power cables shall be routed in close proximity to the equipotential ground plane with the signal and control cables separated from power cables as far as practicable. The equipotential plane shall be connected to the building structure shell and earth electrode subsystem at many points.

### 10-17. Lightning protection

Design guidance and requirements for lightning protection systems for conventional installations are contained in TM 5-811-3 (chapter 3) Electrical Design: Lightning and Static Electricity Protection; TM 5-811-6; and TM 5-785, Engineering Weather Data.



**TM 5-691**

- a. Extensions of commercial power transmission lines within the boundaries of the individual C4ISR site shall be protected by grounded overhead static conductors. The same principle shall be employed in the design of the subtransmission or distribution class of aerial power lines rated below 115 kV. To provide ample spacing of phase conductors and grounded overhead static wires, the distribution class of aerial lines shall be designed as though rated at 115 kV. Designs shall stipulate installation of station-class metal oxide surge arresters on aerial lines when they are to serve technical loads. A minimum of three surge arresters shall be installed at each line tap, at each line support structure (on opposite sides of each line tap), at each pole where an overhead-to-underground transition occurs, and on both sides of line-sectionalizing switches. Designs for aerial service entrance conductors for technical facilities shall incorporate surge arresters, surge-protective capacitors, and metal oxide varistors (MOV).
- b. The C4ISR site primary substation transformer(s) shall be protected by an aerial lightning-protection system. When practical, transformers shall be installed within the zone of protection provided for the commercial power line(s).
- c. C4ISR facilities shall be protected against damage from lightning through conformance with the requirements stipulated in the documents referenced in this paragraph unless more stringent requirements are imposed by the using government agency.

**10-18. Communications and alarms**

Communications, instrumentation, and control links shall be provided between the C4ISR site primary substation and the C4ISR facility. The instrumentation and control system shall permit remote control of the primary substation distribution breakers from the CR. The system shall permit the control of electrically operated circuit breakers in the C4ISR facility from either the CR or the switchgear room(s). The position of all low- and medium-voltage circuit breakers shall be displayed locally at the switchgear and remotely in the CR. Metering shall be provided locally and duplicated in the CR. Abnormal operating conditions shall be annunciated audibly and visually at the switchgear and remotely in the CR. The control system shall consist of a programmable logic controller (PLC) based supervisory control and data acquisition (SCADA) system.

- a. The communications system in equipment areas shall be a high-quality voice-grade system designed to operate in an acoustically noisy environment. The primary communications link shall be a page-talk system that allows audible paging over a public address system as well as individual conversations on a selected party line. An administrative telephone system shall be provided for normal communications in the rest of the facility.
- b. The fire alarm and detection system shall comply with NFPA 72, National Fire Alarm Code, and the current approvals issued by Underwriters Laboratories (UL), Factory Mutual System, or another nationally recognized testing laboratory. The fire alarm signaling system shall automatically initiate fire alarm signaling devices whenever an automatic fire detector is activated, a manual pull station is activated, or a water flow alarm signifying sprinkler activation is activated. The fire alarm system shall have a central annunciator for the facility that receives the alarm from the various zones in the facility and transmits the alarm to the central fire alarm receiving station or directly to the fire department. The system also activates all other devices that might be required (such as smoke control systems and audible or visual alarm signals). The system shall transmit a trouble alarm any time a condition occurs that warrants a trouble alarm. The system shall be capable of operating with a single break or signal ground fault condition in the signal-initiating or alarm-sounding circuits. To maximize reliability and continuity of service, dual sources of electrical power with automatic switchover to the backup source upon loss of primary power shall be provided for the fire alarm systems in accordance with NFPA 72. Where a

computer system of any kind or size is used to receive or process signals, an UPS shall be provided in accordance with NFPA 72. The UPS system for the fire alarm system shall be separate from the UPS system for the electrical power service for the C4ISR operation.

(1) The Central fire station at each site shall be the primary interface point to the fire alarm system. This interface shall provide the means to indicate the location of alarms which may be activated at the site and to signal the status of alarm supervisory and monitoring circuits. A secondary interface duplicating these alarm and supervisory signals may be provided where appropriate at another location. Fire alarm systems may be used to control functions other than alarm initiation and firefighter notification. These functions may be fire or non-fire related such as local evacuation signals, equipment or process shutdown signals, elevator capture, and activation of automatic fire suppression systems. However, the design shall be such that a fault in the external control function shall not prevent the normal operation of the fire alarm system. Examples of special interfaces are:

(a) Fire barriers between enclosures or operating areas may be needed to prevent the spread of fire. These barriers may need to be open during operations. An automatic closing interlock with the fire detection system will be required to close the barriers upon detection of a fire.

(b) In some areas, high-voltage transformers and switchgear may have to be de-energized when a deluge or sprinkler system is activated.

(c) Selected ventilation systems may have to be de-energized when a fire is detected within their zone of operation.

(d) Automatic shutdown of electric power may be required for computer-electronic data processing equipment in those areas where fire may operate sprinkler heads before manual shutdown could be accomplished. A manual reset shall be provided to re-energize the interrupted electrical system.

(2) The occurrence of any alarm, trouble, or supervisory signal shall be automatically transmitted to the central station equipment. Transmitted signals may be grouped into zones which define the localized area where the signal originates. All signaling line circuits shall be monitored for integrity. In addition to direct connection, either time or frequency division, multiplexing may be used for signal transmission. Alarms that respond to flow of water shall be provided wherever a sprinkler system is installed. These alarms shall comply with the requirements of the NFPA standard for the type of signaling system used. A manual fire notification method such as manual fire alarm boxes shall be provided and located in accordance with the appropriate NFPA standard. Combined watch reporting and fire alarm systems, if used, shall be in accordance with the appropriate NFPA standard.

(3) Automatic detection systems may be used to supplement or to actuate extinguishing systems. Detector spacing shall be in accordance with NFPA 72.

(a) Heat-actuated detectors (HADs) are appropriate when speed of detection is not the prime consideration, the space is small or confined and rapid heat buildup is expected, or ambient conditions do not permit the use of other detection devices.

(b) Flame-actuated detectors are appropriate when rapid detection is of prime importance in high hazard areas such as fuel-loading platforms, industrial process areas, high ceiling areas, and atmospheres where explosions or very rapid fires may occur. Since flame-actuated detectors must have a direct line-of-sight to the flame in order to operate, the number of devices and their aiming must be carefully engineered. False trips from extraneous radiation sources are also possible. For the above



**TM 5-691**

reasons, use of this type of device shall require careful coordination among the fire protection engineer and the equipment manufacturer.

(c) Smoke detectors shall be installed in all areas where required by the appropriate NFPA standard or by the authority having jurisdiction (AHJ). Smoke detectors shall be of a type operating on one of the principles described in NFPA 72. A mixture of detector types may be appropriate. Location and required spacing of smoke detectors shall be determined by the methods of NFPA 72. Spacing shall be based upon threshold fire size, fire growth rate, and ceiling height as described in these standards.

(4) The outside portions of fire alarm and supervisory systems shall comply with the latest revisions of NFPA 72; NFPA 1221, Installation, Maintenance, and Use of Public Fire Service Communication Systems; and ANSI C2, National Electrical Safety Code, as appropriate for the location. Outside cable installations for fire alarm and supervisory systems shall comply with the standards for telephone cable systems. Where poles are jointly used for electric power distribution and for supporting fire alarm and telephone cables, fire alarm cable shall be placed below the telephone cable. Fire alarm cables which are installed in underground ducts shall be distinctively marked within manholes that are shared with other communications cables and shall be kept physically separated from all power conductors. Exterior fire alarm pull boxes and emergency-reporting telephones shall be installed in weatherproof housings manufactured specifically for the mechanism.

(5) Auxiliary shunt trip circuits shall conform to the requirements of NFPA 72, unless a manufacturer's recommendation modifies these requirements. All equipment connected to auxiliary loops shall be listed for service under NFPA 72 rules. Fire detectors and other alarm initiating devices shall be connected in a fail-safe configuration.

(6) All means of interconnecting equipment, devices, and appliances in new fire alarm systems shall be monitored for integrity. Allowable exceptions to this requirement shall be as noted in NFPA 72. Existing circuits that are not monitored for integrity shall be subject to periodic tests and inspections at a more frequent rate than for monitored circuits. Monitoring integrity of circuits may be by ac or dc or through digital methods, with continuous line monitoring equipment suitable to detect a short circuit, open circuit, or unintentional ground fault. Devices for alarming detection of faults in all monitored circuits shall be located in the central station.

(7) Provision shall be made for supervising all those system components and conditions where abnormalities may adversely affect the performance of the fire protection system. Sprinkler systems shall be supervised in accordance with NFPA 72. Any alarm or fire-related auxiliary device, including fan bypass switches, which require manual resetting after operation, shall provide an audible and visible indication at the central station when in the non-reset position.

(8) Each new building or facility shall be provided with an emergency notification system (ENS) for announcing fire alarm informational and evacuation messages. A public address (PA) system may serve as the ENS for new or existing buildings if approval for such use is granted by the using Government agency. ENSs used for this purpose shall be in accordance with NFPA 72.

**10-19. Electromagnetic interference/radio frequency interference**

Effective shielding to limit EMI and EMP to within the required limits for C4ISR facilities is dependent upon the grounding and bonding practices required to provide a unified facility ground. The grounding practices for the earth electrode system, the building structure, the lightning protection system, the power system, and the signal reference system must be integrated to achieve a unified ground system. The particular grounding practices for each of these subsystems are illustrated in MIL-HDBK-419A,

Grounding, Bonding, and Shielding for Electronic Equipment and Facilities. Additionally, specifications and installation designs for new equipment shall include requirements to assure electromagnetic compatibility (EMC) between the equipment and the operating environment. These requirements shall serve to minimize the susceptibility of the new equipment to EMI that may be present in the operating environment as well as to limit radiated emissions by the equipment to the environment and to existing equipment.

#### **10-20. Personnel and electrical system protection**

Electrical systems, both interior and exterior, shall be designed to prevent injury to personnel and damage to equipment. The design for personnel and system protection shall be in accordance with appropriate sections of NFPA 70 and these criteria.

- a. Where unusual circumstances in the use of low voltage present a shock hazard to personnel from possible line-to-ground contact, ground fault circuit interrupter (GFCI) devices shall be installed to supplement, but not replace, the normal system protection devices.
- b. System protection shall comply with IEEE 242. Protection for systems shall be designed to limit damage to equipment and to minimize interruption of power consistent with reliability of power required by the loads.
- c. Protective devices shall be coordinated to achieve sequential operation of fault-clearing devices from the load or fault toward the source. Differential protection should be provided when the cost for the protection would be less than the cost of the equipment damage that it could prevent. Where differential protective relaying is used for generator, motor, or transformer protection, the generator load breaker, the motor feed breaker, and the transformer secondary breaker (as applicable) shall be included in the differential zone. Where bus differential protection is used, circuit breakers on the bus shall be included in the differential zone. Exceptions will be noted. The design shall include exact settings for all protective relays.

#### **10-21. Cathodic protection**

Underground metallic process piping and vessels shall be cathodically protected where required by the specification for a facility. Cathodic protection systems shall be designed by a NACE-accredited corrosion specialist. Suitable drawings shall be prepared to designate the overall layout of the pipe lines to be protected and the location of significant items of structure hardware, corrosion control test stations, electrical bonds, and insulating flanges and couplings. Design requirements shall be governed by the National Association of Corrosion Engineers (NACE) RP0169, Control of External Corrosion on Underground or Submerged Metallic Piping Systems. For design and installation details, see TM 5-811-7, Electrical Design, and Cathodic Protection.

- a. All natural gas, recirculating cooling water, hazardous chemical, or other designated metallic pipe lines shall be protected. Fire water mains may require protection depending upon the materials of construction utilized, the location of the main in the plant, soil samples taken at the plant site, and ground voltage gradients near the pipes.
- b. Cathodic protection for underground flammable/combustible liquid storage tanks and piping shall comply with NFPA 30. The interior of aboveground steel water tanks shall be protected by a cathodic protection system when the calcium content of the water is less than 18 ppm or when the calcium content is between 18 and 55 ppm and the sulfate content is greater than 25 ppm.

**TM 5-691**

c. Insulating devices consisting of flange assemblies prefabricated insulating joints, unions, or couplings shall be installed at the termination of service line connections and entrance piping to prevent electrical continuity with other piping systems. These devices shall be properly rated for temperature, pressure, and dielectric strength. Lightning and fault current protective anodes shall be installed at insulating flanges or devices.

## APPENDIX A

### REFERENCES

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#### Required Publications

##### Government Publications

###### *Department of Defense:*

MIL-HDBK-419A

Grounding, Bonding, and Shielding for Electronic Equipment and Facilities (Cited in paragraphs 6-5m, 10-16, 10-19)

MIL-HDBK-1008C

Fire Protection for Facilities Engineering, Design, and Construction (Cited in paragraphs 6-1, 6-5a, 6-5c, 6-8d, 6-10j, 6-12, 6-19a, 6-23a)

MIL-HDBK-1022

Petroleum Fuel Facilities (Cited in paragraph 6-19)

MIL-STD-882

System Safety Program Requirements (Cited in paragraph 2-2c(1))

MIL-STD-1472

Human Engineering Design Criteria for Military Systems, Equipment, and Facilities (Cited in paragraphs 2-2b, 5-6)

MIL-STD-1474

Noise Limits for Military Material (Cited in paragraph 5-6)

###### *Department of the Army:*

AR 11-27

Army Energy Program (Cited in paragraph 7-17b)

AR 200-1

Environmental Protection and Enhancement (Cited in paragraph 8-1b)

AR 420-49

Utility Services (Cited in paragraphs 7-1d, 7-18d, 8-1, 8-1b)

AR 420-79

Natural Resources; Land, Forrest, and Wildlife Management (Cited in paragraph 8-1b)

DA PAM 40-501

Hearing Conservation Program (Cited in paragraph 5-6)

**TM 5-691**

TM 5-650

Repairs and Utilities: Central Boiler Plants (Cited in paragraph 7-19)

TM 5-653

Steam, Hot Water and Gas Distribution Systems: Inspection and Preventive Maintenance Services (Cited in paragraph 7-17e)

TM 5-660

Maintenance and Operation of Water Supply, Treatment and Distribution Systems (Cited in paragraphs 8-9b, 8-15)

TM 5-685

Operation, Maintenance, and Repair of Auxiliary Generators (Cited in paragraph 9-1)

TM 5-785

Engineering Weather Data (Cited in paragraph 10-17)

TM 5-805-4

Noise and Vibration Control (Cited in paragraph 7-32)

TM 5-810-1

Mechanical Design Heating, Ventilating, and Air-Conditioning (Cited in paragraphs 7-1c, 7-1f, 7-15b)

TM 5-810-4

Compressed Air (Cited in paragraph 8-7)

TM 5-810-5 (Cited in paragraph 8-16)

Plumbing

TM 5-811-1

Electrical Power Supply and Distribution (Cited in paragraphs 10-4a, 10-7a, 10-9, 10-16)

TM 5-811-2

Electrical Design, Interior Electrical Systems (Cited in paragraphs 10-12, 10-16)

TM 5-811-3

Electrical Design: Lightning and Static Electricity Protection (Cited in paragraph 10-17)

TM 5-811-6

Electric Power Plant Design (Cited in paragraphs 10-5a, 10-17)

TM 5-811-7

Electrical Design, Cathodic Protection (Cited in paragraph 10-21)

TM 5-814-1

Sanitary and Industrial Wastewater Collection, Gravity Sewers and Appurtenances (Cited in paragraphs 4-3b(2), 8-16c)

TM 5-814-2

Sanitary and Industrial Wastewater Collection-Pumping Stations and Force Mains (Cited in paragraphs 4-3b(2), 8-16c)

TM 5-815-3  
Heating, Ventilation and Air Conditioning (HVAC) Control Systems (Cited in paragraph 7-31)

TM 5-818-1  
Soils and Geology: Procedures for Foundation Design of Buildings and Other Structures (except Hydraulic Structures) (Cited in paragraph 5-2)

TM 5-855-4  
Heating, Ventilating, and Air Conditioning of Hardened Installations (Cited in paragraph 8-4a)

TM 5-858-5  
Designing Facilities to Resist Nuclear Weapons Effects: Air Entrainment, Fasteners, Penetration Protection, Hydraulic Surge Protection Devices, and EMP Protective Devices (Cited in paragraph 7-9d)

TM 5-858-7  
Designing Facilities to Resist Nuclear Weapon Effects - Facility Support Systems (Cited in paragraph 7-10a)

#### *Code of Federal Regulations*

28 CFR 36  
Americans with Disabilities Act (ADA) (Cited in paragraph 8-1d)

29 CFR 1910.151.c  
Occupational Safety and Health Administration (OSHA) (Cited in paragraph 8-14a)

29 CFR 1926  
Safety and Health Regulations for Construction (Cited in paragraph 4-3b (5))

40 CFR 141  
National Primary Drinking Water Regulations (Cited in paragraph 8-13)

40 CFR 280  
Underground Storage Tanks (Cited in paragraph 8-5d)

#### *Other Government Documents:*

Federal Information Processing Standards (FIPS) Pub 94  
Guideline of Electrical Power for ADP Installations (Cited in paragraph 10-16)

#### Non-Government Publications

*American National Standards Institute (ANSI):*  
1430 Broadway, New York, NY 10018

ANSI A13.1  
Scheme for the Identification of Piping Systems (1996) (Cited in paragraphs 7-17c, 9-1.d)

**TM 5-691**

ANSI B31.3

Code for Pressure Piping, Chemical Plant, and Petroleum Refinery Piping (1999) (Cited in paragraphs 8-4, 8-7, 8-17b)

ANSI C2

National Electrical Safety Code (1997) (Cited in paragraph 10-18c(4))

ANSI C50.10

Rotating Electrical Machinery- Synchronous Machines (DOD Adopted) (1990) (Cited in paragraph 10-5b)

ANSI C84.1

Electrical Power Systems and Equipment – Voltage Ratings (60 Hertz) (1995) (Cited in paragraphs 10-3a, 10-15f)

ANSI Z358.1

Emergency Eyewash and Shower Equipment (1998) (Cited in paragraph 8-14a)

*American Society for Testing and Materials (ASTM):*

100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ASTM E779

Standard Test Method for Determining Air Leakage Rate by Fan Pressurization (1992) (Cited in paragraph 7-10d)

ASTM D-92

Standard Test Method for Flash and Fire Points by Cleveland Open Cup (1998) (Cited in paragraph 6-23b)

ASTM D2680

Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) and Poly (Vinyl Chloride) (PVC) Composite Sewer Piping (1995) (Cited in paragraph 4-3c)

*American Society of Civil Engineers (ASCE)*

345 East 47<sup>th</sup> Street, New York, NY, 10017-2398

ASCE 77

Design and Construction of Urban Stormwater Management Systems (1993) (Cited in paragraphs 4-3b(2), 4-3b(3))

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

1791 Tullie Circle, NE, Atlanta, GA 30329

ASHRAE 15

Safety Code for Mechanical Refrigeration (1994) (Cited in paragraphs 7-21b, 7-27)

ASHRAE 62

Ventilation for Acceptable Indoor Air Quality (1989) (Cited in paragraph 7-10g)

*American Waterworks Association (AWWA):*

6666 West Quincy Avenue, Denver, CO 80235

AWWA C151  
Ductile-Iron Pipe, Centrifugally Casts for Water (1996) (Cited in paragraph 4-3c)

AWWA C651  
Disinfecting Water Mains (1992) (Cited in paragraph 8-9b)

AWWA C652  
Disinfection of Water Storage Facilities (1992) (Cited in paragraph 8-9b)

AWWA C653  
Disinfection of Water Treatment Plants (1997) (Cited in paragraph 8-9b)

AWWA C654  
Disinfection of Wells (1987) (Cited in paragraph 8-9b)

AWWA D100  
Welded Steel Tanks for Water Storage (1996) (Cited in paragraph 8-22)

*Institute of Electrical and Electronic Engineers (IEEE):*  
445 Hoes Lane, P. O. Box 1331, Piscataway, NJ 08855-1331

IEEE C57.110  
IEEE Recommended Practice for Establishing Transformer Capability When Supplying Non-Sinusoidal Load Currents (1998) (Cited in paragraph 10-9a)

IEEE 141  
IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (1993) (Cited in paragraph 10-5f)

IEEE 142  
IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (1991) (Cited in paragraph 10-16)

IEEE 242  
IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (1986) (Cited in paragraphs 10-5e, 10-8c, 10-20b)

IEEE 446  
IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (1995) (Cited in paragraphs 10-15c, 10-15g, 10-15j(2))

IEEE 485  
IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications (1997) (Cited in paragraph 10-15j(3))

IEEE 519  
IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems (1992) (Cited in paragraph 10-3e)



**TM 5-691**

IEEE 1100

IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Cited in paragraphs 10-16, 10-16f)

*National Association of Corrosion Engineers*  
1440 South Creek Drive, Houston, TX 77084

NACE RP0169

Control of External Corrosion on Underground or Submerged Metallic Piping Systems (1996) (Cited in paragraph 10-21)

*National Electrical Manufacturer's Association (NEMA):*  
2101 L Street, NW, Suite 300, Washington, DC 20037

NEMA MG 1

Motors and Generators (DOD Adopted) (1998) (Cited in paragraph 10-5b)

*National Fire Protection Association (NFPA):*  
One Batterymarch Park, P. O. Box 9101, Quincy, MA 02269-9101

NFPA 10

Portable Fire Extinguishers (1998) (Cited in paragraphs, 6-5, 6-5b, 6-14c)

NFPA 13

Installation of Sprinkler Systems (1999) (Cited in paragraphs 6-5a, 6-5b, 6-5c, 6-5f, 6-5h, 6-5n, 6-10c, 8-12b(6))

NFPA 14

Installation of Standpipe and Hose Systems (1996) (Cited in paragraphs 6-5b, 6-12d)

NFPA 15

Water Spray Fixed Systems for Fire Protection (1996) (Cited in paragraph 6-5b)

NFPA 20

Standard for the Installation of Stationary Fire Pumps for Fire Protection (1999) (Cited in paragraphs 6-10c, 6-11, 6-11c)

NFPA 22

Water Tanks for Private Fire Protection (1998) (Cited in paragraphs 6-10c, 8-22)

NFPA 24

Private Fire Service Mains (1995) (Cited in paragraphs 6-10c, 6-10k, 8-12b(3))

NFPA 30

Flammable and Combustible Liquids Code (1996) (Cited in paragraphs 6-19, 6-19d, 7-16, 8-5a(1), 8-5c, 8-5d, 8-5e, 8-5f, 8-5g, 8-10b, 10-21b)

NFPA 37

Stationary Combustion Engines and Gas Turbines (1998) (Cited in paragraphs 6-14, 6-19, 7-13, 7-16, 8-5a(1), 8-5f, 8-8)

## NFPA 70

National Electrical Code (1999) (Cited in paragraphs 6-12c, 6-14, 6-18a, 6-23a, 6-23c, 7-14c, 7-15, 10-1, 10-16, 10-20)

## NFPA 72

National Fire Alarm Code (1999) (Cited in paragraphs 6-13c, 6-14d, 10-18b, 10-18b(3), 10-18b(3)(c), 10-18b(4) through (8))

## NFPA 75

Electronic Computer/Data Processing Equipment (1999) (Cited in paragraph 6-12)

## NFPA 90A

Installation of Air Conditioning and Ventilation Systems (1999) (Cited in paragraph 7-20)

## NFPA 92A

Smoke-Control Systems (1996) (Cited in paragraph 7-20)

## NFPA 101

Life Safety Code (1997) (Cited in paragraphs 5-7, 6-13)

## NFPA 110

Emergency and Standby Power Systems (1999) (Cited in paragraphs 6-14, 7-12, 7-13, 7-16, 8-6f)

## NFPA 111

Stored Electrical Energy Emergency and Standby Power Systems (1996) (Cited in paragraphs 6-15, 7-14)

## NFPA 211

Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances (1996) (Cited in paragraph 7-13)

## NFPA 214

Water Cooling Towers (1996) (Cited in paragraph 6-25)

## NFPA 230

Fire Protection of Storage (1999) (Cited in paragraph 6-20)

## NFPA 1221

Installation, Maintenance, and Use of Public Fire Service Communication Systems (1999) (Cited in paragraphs 10-18b(4))

*Underwriters' Laboratories, Inc. (UL)*

333 Pfingsten Road, Northbrook, IL 60062-2096

## UL 723

Safety Test for Surface Burning Characteristics of Building Materials (1996) (Cited in paragraph 8-21a)

## GLOSSARY

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### Section I

#### Abbreviations

**ABS**

Acrylonitrile-butadiene-styrene

**AC**

Alternating current

**ADA**

Americans with Disabilities Act

**ADP**

Automated data processing

**AEI**

Architectural and engineering instructions

**AHJ**

Authority having jurisdiction

**ALTC**

Automatic load tap changer

**ANSI**

American National Standards Institute

**AR**

Army Regulation

**ASCE**

American Society of Civil Engineers

**ASHRAE**

American Society of Heating, Refrigeration, and Air Conditioning Engineers

**ASME**

American Society of Mechanical Engineers

**ASTM**

American Society for Testing and Materials

**AT/FP**

Anti-terrorism/force protection

**AWWA**

American Waterworks Association

**TM 5-691**

**BT**

Bus-tie

**BTU**

British thermal unit

**C3I**

Command, control, communications, and intelligence

**C4ISR**

Command, control, communications, computer, intelligence, surveillance, and reconnaissance

**C**

Centigrade

**CAD**

Computer-aided drafting

**CBR**

Chemical, biological, and radiological

**CCTV**

Closed circuit television

**cm**

Centimeter

**CEGS**

Corps of Engineers guide specification

**CES**

Critical equipment/system

**CFR**

Code of Federal Regulations

**CI**

Cast iron

**CM**

Configuration management

**CONUS**

Continental United States

**CP**

Collective protection

**CR**

Control room

**G-2**

**CRT**

Cathode ray tube

**CSR**

Cold standby redundant

**CWA**

Clean Water Act

**DA PAM**

Department of the Army Pamphlet

**dB**

Decibel

**dBa**

Decibel (Audio): sound pressure level above reference level of 0.00002 newton/cm<sup>2</sup>

**DC**

Direct current

**DOD**

Department of Defense

**DODISS**

DOD Index of Specifications and Standards

**DPGDS**

Deployable power generation and distribution system

**DPW**

Director of Public Works

**DX**

Direct expansion

**EM**

Electromagnetic

**EMC**

Electromagnetic compatibility

**EMI**

Electromagnetic interference

**EMP**

Electromagnetic pulse

**ENS**

Emergency Notification System

**TM 5-691**

**EPA**

Environmental Protection Agency

**EPAG**

Electric power availability goal

**EPAR**

Electric power availability requirement

**F**

Fahrenheit

**FIPS**

Federal Information Processing Standards

**fps or ft/s**

Feet per second

**ft**

Feet

**gpm**

Gallons per minute

**GFCI**

Ground fault circuit interrupter

**GFE**

Government furnished equipment

**GHz**

Gigahertz

**H<sub>2</sub>**

Hydrogen

**HAD**

Heat actuator detector

**HEMP**

High altitude electromagnetic pulse

**HEPA**

High efficiency particulate air

**HFE**

Human factors engineering

**HVAC**

Heating, ventilating, and air conditioning

**G-4**

**HVAC&R**

Heating, ventilating, air conditioning & refrigeration

**Hz**

Hertz

**IEC**

International Electrotechnical Commission

**IEEE**

Institute of Electrical and Electronics Engineers

**IGBT**

Insulated gate bipolar transistor

**IMA**

Installation medical authority

**JCS**

Joint Chiefs of Staff

**kg**

Kilogram

**km**

Kilometer

**kVA**

Kilovolt ampere

**kW**

Kilowatt

**LCB**

Line circuit breaker

**LCC**

Life cycle cost

**LCCA**

Life cycle cost analysis

**LDC**

Line drop compensating

**MCB**

Maintenance circuit breaker

**min**

Minute

**TM 5-691**

**MMI**

Man-machine interface

**MOV**

Metal oxide varistor

**mph**

Miles per hour

**MVA**

Megavolt ampere

**NACE**

National Association of Corrosion Engineers

**NEC**

National Electrical Code

**NEMA**

National Electrical Manufacturers Association

**NFGS**

Naval facilities guide specification

**NFPA**

National Fire Protection Association

**NPDES**

National pollutant discharge elimination system

**NPS**

Non-point source

**O&M**

Operations and Maintenance

**OCONUS**

Outside Continental United States

**OSHA**

Occupational Safety and Health Administration

**pA**

Pascal

**PA**

Public address

**PCE**

Power-conditioning equipment



**PDU**

Power distribution unit

**PIV**

Post indicator valve

**PLC**

Programmable logic controller

**ppm**

Parts per million

**psig**

Pounds per square inch, gage

**PVC**

Polyvinyl chloride

**PWM**

Pulse width modulated

**R/A**

Reliability/Availability

**RAM**

Reliability, availability, and maintainability

**RCM**

Reliability centered maintenance

**RFI**

Radio frequency interference

**RMS**

Root mean square

**RPTBP**

Reduced pressure type backflow preventer

**RTU**

Remote terminal unit

**s**

Second

**SCADA**

Supervisory control and data acquisition

**SCR**

Silicon-controlled rectifier

**TM 5-691**

**SDWA**

Safe Drinking Water Act

**SE**

Systems engineering

**SEDB**

Systems engineering database

**SMACNA**

Sheet Metal Air Conditioning Contractors National Association

**STS**

Static transfer switch

**TFA**

Toxic-free area

**THD**

Total harmonic distortion

**TIMA**

Thermal Insulation Manufacturers Association

**TM**

Technical Manual

**UFC**

Unified Facilities Criteria

**UL**

Underwriters Laboratories

**UPS**

Uninterruptible power supply

**USACE**

U.S. Army Corps of Engineers

**VAR**

Volt-ampere reactive

**VPI**

Vacuum pressure impregnated

**wg**

Water gage

**WQA**

Water Quality Act

## **Section II**

### **Terms**

#### **Control Room**

The area(s) from where power generation and supporting systems are controlled.

#### **Critical Bus**

A critical bus supplies the critical equipment/systems directly through feeders or branch circuits which originate at the bus and terminate at the input terminals of the equipment or control devices such as reduced-voltage motor starters. This definition excludes the use of frequency converters/inverters and transformers that alter the voltage between the bus and the equipment.

#### **Critical Equipment/Systems**

Critical equipment/systems include those items of equipment or systems that directly supply power to equipment and systems used to perform the primary mission(s) of the C4ISR site.

#### **Critical Load**

That portion of the technical load used to successfully accomplish the site missions and having a requirement for 100 percent continuity in power service, such as from the Uninterruptible Power Supply (UPS) system. These loads also include any equipment which, upon loss of power, will create an unacceptable impact on the mission or mission equipment.

#### **Design Agency**

The agency responsible for the overall design of the facility.

#### **Emergency Load**

Emergency lights, exit lights, fire suppression systems, and similar life-safety loads.

#### **Essential Equipment/Systems**

All systems other than the critical equipment/systems (CESs) are to be considered essential if they must operate to supply the CESs directly. This includes the support loads for the critical loads, security lighting, intrusion detection, entry control, and security monitoring equipment.

#### **Essential Load**

That portion of the technical load that directly supports routine accomplishment of site missions. Loads include general lighting and power systems, HVAC, and similar loads which can tolerate power outages without loss of data or without adversely affecting the vital C4ISR missions.

#### **Loading/Unloading Areas**

The area(s) which serve as a receiving/distribution point for supplies coming into the C4ISR facility. A loading platform or dock.

#### **Mimic Board**

A switchgear or control panel, or an assembly consisting of a single-line diagram of the main connections of a system constructed on the face, with instruments, switches, or status lights mounted in appropriate locations.

#### **Mission Administration**

All administrative areas such as offices, day rooms, kitchens, and sleeping areas.

## TM 5-691

### **Mission Area**

The area(s) within the facility that are specifically designated for carrying out the command, control, communications, or intelligence mission of that facility. An example of a mission area would be a computer room where information related to C4ISR is gathered or processed.

### **Non-Essential Load**

That portion of the operational load that indirectly supports the operations at the C4ISR site. This generally includes exterior and interior lighting and loads associated with administration and housing functions.

### **Off-Site Power Mode**

The mode of operation in which off-site power exclusively is used for facility operations.

### **On-Site Power Mode**

The mode of operation in which all power is generated by the on-site power supply system, and operational steps are taken to isolate the C4ISR power system from the outside operational environment and the commercial power source.

### **Off-Site/On-Site Power Mode**

The mode of operation allowing paralleling of off-site and on-site power supplies to permit transition of the system load from one to the other without power interruption or unacceptable perturbation.

### **Continuous Operation in the On-Site Power Mode**

In this mode, on-site power generation is the only mode available at this C4ISR power plant location.

### **Steady-State Variation**

The effect of periodic and random deviations of instantaneous voltage or frequency on the mean steady-state value, at any constant load, the limit of such effect being expressed as a plus and minus percent of nominal value.

### **Technical Load**

That portion of the operational which consists of general lighting and heating, ventilating, and air-conditioning (HVAC) systems necessary to maintain normal operations and loads directly associated with the C4ISR missions at the site.

### **Transmit/Receive Stations**

Enclosed structures outside of the main facility which transmit and/or receive satellite, microwave, or RF transmissions.

### **User**

The using Government Agency.

### **Using Government Agency**

The Government Agency that will be responsible for completing the site missions and will have operational authority for the facility.

**TM 5-691**

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