TECHNICAL MANUAL

MAINTENANCE OF MECHANICAL AND ELECTRICAL EQUIPMENT AT COMMAND, CONTROL COMMUNICATIONS, INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE (C4ISR) FACILITIES

RECOMMENDED MAINTENANCE PRACTICES

HEADQUARTERS, DEPARTMENT OF THE ARMY
15 APRIL 2001

REPRODUCTION AUTHORIZATION/RESTRICTIONS

Technical Manual

No. 5-692-1

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, *15 April 2001*

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

Maintenance of Mechanical and Electrical Equipment at C4ISR Facilities

Recommended Maintenance Practices

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1-1. Purpose

This document provides generic guidance to agencies responsible for the development and implementation of maintenance programs for site utility systems at Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) facilities. TM 5-692-1 describes the activities which must be performed to maintain mechanical and electrical equipment at a minimum level of operational readiness. TM 5-692-2, the companion manual to TM 5-692-1, describes commonly implemented design features of various mechanical and electrical systems.

1-2. Scope

The program guidance and system specific maintenance requirements advanced in this manual are applicable in part or total to all C4ISR sites.

1-3. References

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

1-4. Standard of performance

The program guidance and system specific maintenance requirements advanced in this manual are to be considered the minimum required standards of performance for such efforts and must be augmented by equipment manufacturer's detailed operation and maintenance instructions and other site-specific maintenance requirements as local mission reliability requirements dictate.

CHAPTER 2

MAINTENANCE PROGRAM AND SAFETY CONSIDERATIONS

2-1. General

Mission readiness at Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) sites rests on the reliability of the electrical power supply and other site utilities systems. This reliability in turn rests on these systems being properly serviced and maintained.

a. Maintenance planning. Since maintenance work is generally done in the least time possible, maintenance activities should be planned. In addition to ensuring that the necessary materials, tools, parts are assembled and prepared for use in advance of the work, the maintenance activity plan should also cover all aspects of the activity which may include the following.

(1) Scheduling with operations

(2) Site access

(3) Calibrated test equipment for each test required

(4) Necessary lighting, electrical power, and service air to perform the work

(5) Cleaning aids consisting of clean, white, lint-free cloths; solvents; vacuum cleaner; and dry compressed air

(6) Personnel safety equipment required for the specific maintenance activities being performed

b. Maintenance program. A total maintenance program for C4ISR sites must contain elements of both preventive and predictive maintenance. Preventive maintenance is the systematic care and servicing of equipment and facilities to prolong their useful life. Predictive maintenance consists of the performance of periodic equipment inspections to identify and monitor symptoms (such as increasing wear, abnormal vibrations, or increasing power usage) which indicate that mechanical failure of a piece of equipment may be approaching. The goal of predictive maintenance is to develop an awareness of developing problems so that needed repairs can be made on a planned rather than on an emergency basis and unscheduled system down time resulting from unpredicted equipment failure is avoided. Effective execution of a total site maintenance program requires the implementation of the following elements.

(1) In general, people tend to concentrate their efforts on performing that work which is important to their supervisors. Therefore, successful implementation of an effective maintenance program for utility systems at any C4ISR site must be based upon the active interest, support, and involvement of the facility commander.

(2) Training and instruction of maintenance personnel, operators, and users of the particular equipment systems in proper operation, maintenance, and safety procedures

(3) Systematic, periodic inspection and servicing of plant systems and equipment by skilled maintenance personnel

(4) Assignment of specific maintenance responsibilities to skilled maintenance personnel and to operators of equipment

(5) Continuing supervision of the site maintenance program

(6) Periodic utility systems maintenance inspections to ensure the maintenance program is being implemented

2-2. Maintenance management

The maintenance management approach required to ensure utility system reliability will vary from location to location depending upon the site location, mission, and number and complexity of site utility systems as well as other factors. The mechanics of implementation may also differ between locations with a small site using manual methods and a large facility requiring a computer to keep maintenance records and prepare maintenance reports. The approach to maintenance management for each site will have some basic requirements in common, regardless of the size or complexity of the equipment systems to be maintained. Appendix B provides recommended guidance for the implementation of each of the following basic requirements.

a. Definition of local equipment systems

b. Development of an appropriate maintenance records system

c. Development of an appropriate spare parts inventory control system

d. Vigorous implementation of the systems developed above

2-3. Maintenance training

Standard training courses for utility system maintenance personnel are not available and apprenticeship training programs operated by local craft unions have been found not to be specific enough to directly satisfy facility operators' training needs. Typically, electric or public utilities either hire a journeyman craftsman in one of the crafts described above and then train him in the specific requirements of the job he is to perform, or hire untrained individuals with either a mechanical or an electrical aptitude and train them completely. The C4ISR utility systems operator will have similar options if new maintenance workers are needed. The Bureau of Apprenticeship and Training of the U. S. Department of Labor which has branch offices throughout the United States will develop site-specific apprenticeship training programs based on a job description provided by the facility operator. Development of these training programs is provided at no cost to the facility owner.

2-4. Basic maintenance procedures

The following discussion describes basic maintenance procedures applicable to all types of site utility systems.

a. Inspection. Continuous inspection by plant personnel is necessary to detect and correct mechanical defects or conditions which prevent efficient operation. The following must be checked on a continuing basis.

(1) Each machine has a characteristic operating sound or appearance. A change from this normal sound or appearance requires the supervisor's immediate attention.

(2) Vibration is evidence of basic faults which should be corrected. Loose bearings may be either the cause or the result of vibration. Report all unusual vibration to the supervisor.

(3) Cleanliness is essential for trouble-free performance of mechanical and electrical equipment. Moisture, dirt, and oil cause deterioration of equipment systems.

(4) Conditions which cause excess heat must be eliminated.

(5) Couplings should be checked for misalignment. In cases of mechanical troubles, always check alignment. Misalignment may result in overheated and worn bearings or cause stresses which result in failure of the motor shaft.

(6) Electrical overload shortens the life of a motor and contributes to unreliable performance. Motors are designed for greater mechanical overloads than electrical overloads. The motor shaft, frame, and bearings can stand several times the rated load for long periods of time, but wiring will overheat when overloads as low as 15 to 25 percent are imposed continuously. Electrical overloads increase the temperature of the windings. The allowable temperature rise is usually stamped on the nameplate.

b. Lubrication. Lubrication is an important part of preventive maintenance. Proper lubrication prevents damage to wearing surfaces, reduces the maintenance required, and cuts power costs and equipment outages. Contaminants in lubricants produce wear and assist in the ultimate failure of the lubricated equipment.

(1) Use of the proper type of lubricant for the application is critical to successful maintenance results. Equipment manufacturer's detailed instructions should be consulted in all cases to ensure that the proper lubricant is being used.

(2) In order to avoid plant failures due to improper lubrication, the following lubricating precautions should be observed.

(a) Do not overlubricate. Overlubrication causes antifriction bearings to heat and may damage grease seals; it may also cause damage to the windings in electrical motors.

(b) Do not lubricate totally enclosed or insufficiently guarded equipment.

(c) Keep lubricant containers tightly closed, except when in use, to prevent contamination of the lubricant by the entrance of dust, grit, abrasives, and moisture. Lubricants should be stored in dust-free areas. Before using lubricant containers, the spouts and lips should be wiped; before using grease guns, the gun and fitting should be wiped to ensure the absence of foreign matter.

(3) The principal deteriorating elements in oil are dirt, water, oxidation, and excessive heat. If these are controlled, oil deterioration between lubrication periods is unlikely.

c. Measuring operating temperatures. Equipment cannot be maintained properly, unless limits of safe operating temperatures are known. Safe upper limits of operating temperatures are given by manufacturers and can be obtained on request. Use of touch to determine whether operating temperatures are under these maximum limits is unreliable, especially when operating temperatures are above 125°F. One of the following temperature measuring devices should be used instead.

(1) A hand type portable pyrometer, if available in the range required, provides a satisfactory method for measuring external surface temperatures of mechanical equipment.

(2) An ordinary mercury thermometer without a guard is satisfactory for measuring external surface or bearing temperatures. It should be calibrated for the range of use. Details of the use of a thermometer in each of these applications are as follows.

(a) To measure surface temperature, fasten the thermometer to the surface with adhesive tape with the bulb touching the surface. Use a 1/4 inch layer of glazier's putty to insulate the part of the bulb which does not touch the surface. Read only after indicated temperature has reached a constant value.

(b) To measure bearing temperatures, insert the bare thermometer bulb inside the inspection hole at the top of the bearing. Fit cardboard around the thermometer to cover the inspection hole. Read after a constant value has been reached.

d. Painting. Periodic painting is necessary to protect metal surfaces of equipment from corrosion. The required frequency of painting varies from 1 to 10 years, depending on the type of paint used, the method of application, and the conditions of wear. Always paint metal surfaces before corrosion becomes so severe that equipment is damaged. Surfaces must be prepared before they can be painted; sandblast metal surfaces if practical or clean them thoroughly with sandpaper and a wire brush. Paint should be mixed properly and screened, if necessary, to remove grit and film. Paint containers should be covered when not in use. Brushes, rollers, and spray applicators should be cleaned before and after use.

e. Maintenance tools. An adequate supply of tools is essential to efficient conduct of a site utility system maintenance program. The number and type of tools required will vary depending on the types of utilities systems present at the site. See appendix C for a list of commonly required basic and trade tools.

2-5. General safety considerations

This section describes basic safety concepts and practices which are applicable to the maintenance of all utility systems at C4ISR sites. It is intended that these concepts and practices form the basis for the development, by C4ISR maintenance and safety personnel, of a detailed and comprehensive site-specific maintenance safety program for each C4ISR site. Additional assistance in this effort may be obtained by contacting the local chapter of the National Safety Council. Specific manufacturer's equipment manuals should also be consulted when servicing the equipment, as additional safety procedures not mentioned here may be required.

a. Lighting. Good lighting is very important and is required to avoid injuries due to tripping or slipping. Ensure that adequate lighting is provided throughout the facility and that failed light bulbs are replaced on a regular basis.

b. Housekeeping. Good housekeeping and clean equipment areas will reduce hazards. Keep the plant area and equipment clean and free of unnecessary clutter. Keep the floors dry and clean to reduce slipping hazards.

c. Practical jokes. Do not participate in horseplay or practical jokes at any time while onsite. Activities such as tripping, shoving, pushing, scuffling, acrobatics, or pulling chairs from under people, can often lead to serious accidents and personal injury.

d. Manual lifting. Always employ safe lifting techniques when manually lifting loads. Do not lift objects that are too heavy for one person without help. Lift heavy objects with the leg muscles rather than the back muscles. Squat close to the load to be lifted, keep the back and shoulders straight, distribute the weight equally on both legs, and lift evenly. Make certain the body is not twisted, but rather the whole body is turned by shifting the feet when turning to place an object to the side.

e. Preventive maintenance. A vigorous program of preventive maintenance throughout the facility will have a positive effect on the overall safety program by assuring that all of the safety considerations designed into site equipment remain functional.

f. Attitude. Be safety conscious. Do not enter enclosures marked "High Voltage," and report all defects, malpractices, and safety hazards to supervision.

g. Safety training. A comprehensive safety training program should be developed at each site for site maintenance personnel. Though the content of this program may vary from site to site, each site program as a minimum, should cover the type of material discussed in this manual, the use of individual protective equipment, and electrical safety. The local chapter of the National Safety Council should be contacted regarding additional safety training needs, and prepared training programs and materials.

2-6. Fire safety

In the event of a fire, call the fire department immediately; then, attempt to extinguish the fire with portable equipment.

a. Smoking. Smoke only in designated areas.

b. Combustible materials. Rags and combustibles should be stored in covered fireproof containers, in approved storage areas. Keep fire and open flames away from hazardous or flammable material storage areas.

c. Fire extinguishers. Always be prepared for the possibility of a fire. Ensure an adequate number of the proper type of fire extinguishers are available throughout the facility.

(1) Fire extinguishers should be selected to be compatible with the class of fire considered to be possible in the area where the extinguisher is to be located. Water should not be used on electrical or petroleum-based fires. Fire classifications are as follows.

(a) Class A - Fires in ordinary combustible materials

(b) Class B - Fires in flammable liquids

(c) Class C - Electrical fires

(2) Fire extinguishers must be inspected regularly, and tagged to show they are full and have been

inspected. After each use, the fire extinguishers must be refilled for the next emergency. Personnel must be trained to know the location of area fire extinguishers and how to use them properly. Do not allow CO_2 extinguisher discharge to contact the skin due to the danger of "frost bite" from "dry ice" discharge. The use of an extinguisher in a confined space such as a room may cause suffocation due to lack of oxygen resulting from filling the space with carbon dioxide.

2-7. Maintenance safety

An effective safety program includes the establishment of controls and procedures designed to protect the health and welfare of maintenance personnel. Key elements of such a program are described below.

a. Permit program. Performance of required maintenance or repairs will sometimes require performing actions which are normally prohibited within a facility. With regard to C4ISR facilities, the most obvious examples of such actions are the use of welding and cutting or burning equipment in a potentially flammable area and personnel entry into vessels for purposes of inspection or internal repairs. Where such actions cannot be avoided from an operational standpoint, special care must be taken to allow performance of these actions with maximum safety. A proven technique for assurance that hazardous maintenance functions are performed with maximum safety is the use of a permit system.

(1) Under a permit system, a special permit is required before specified types of maintenance work can be implemented. The permit specifies the type of work to be performed, the location of the work, the start time of the permit, the time the permit is to expire, and any special safety precautions to be taken prior to or during the performance of the work. The permit is initiated by the operating department and accepted by the maintenance department. It should be signed by the operations department manager after he has visited the area where the work is to be done. His signature is evidence that he has visited the site of the work, and as a responsible individual, has verified that all required precautionary safety measures have been taken and that the work may proceed. The permit would then be signed by the maintenance manager as evidence that he, as representative of the maintenance department, has also visited the work site and agrees that it is safe for the work to proceed. The work may then proceed until the time of expiration of the permit. Normally all such permits would be voided in the event of a fire or other site emergency, and would not be considered for reissue until the emergency was over. At least two basic types of permits should be used at the C4ISR sites with others added to the system as operating experience requires. These are for hot work (welding, cutting, open flame) and vessel entry.

(2) Among the precautions which should be taken prior to issuance of a hot work permit are the following.

(a) The equipment has been emptied and cleaned of all flammable material.

(b) Test for the presence of combustible vapors.

(c) Flammables in the surrounding area should be removed or protected from the effects of the hot work.

(d) Assignment of a "fire watch" during and following the work to verify that no unnoticed or slow-burning fires have been started by the work.

(3) Precautions to be taken prior to issuance of a vessel entry permit include the following:

(a) Emptying and cleaning the vessel of its contents to the maximum extent possible.

(b) Blinding all openings from which materials could flow into the vessel.

(c) Providing adequate positive ventilation for the vessel.

(d) Locking out all equipment installed on the vessel.

(e) Sampling tank atmosphere to determine the presence of toxic vapors or an oxygen deficient atmosphere.

(f) Proving adequate safety equipment for the man entering the vessel which could include life lines and oxygen supply equipment.

(g) Assigning an individual at the bin entrance whose duty is to watch the workers inside the vessel and aid them in exiting the vessel should trouble occur.

b. Lockout/tagging program. Prior to removal of any protective guards or covers from any moving machinery preparatory to performing maintenance on the equipment, the machine must be locked out of service. Locking out a piece of equipment is accomplished by turning the handle on the main circuit breaker of the equipment's main power (not control) circuit to the ~~open~~ position and locking it in place by padlocking. Where more than one craft (e.g., machinists and electricians) are involved in the repair of a piece of equipment, each craft should have its own separate padlock to lock the equipment out of service. After all padlocks are in place, an attempt should be made to start the locked out equipment to verify that it has, in fact, been locked out. The person from each craft actually servicing the locked out equipment should hold the key to his craft's padlock. As each craft completes its planned maintenance work on the locked-out equipment, it removes its padlock. When all padlocks have been removed, the equipment is ready to be returned to service.

c. Maintenance access. Maintenance personnel must be aware of areas within the facility with special access requirements and follow the rules associated with those areas while carrying out maintenance activities. Some facilities have areas which one person may not enter alone. Some facilities refer to these as "No-Lone" or "Buddy" areas. These areas are typically not visited routinely, so it could be a long time before someone working alone in the area who had an accident would be discovered. In addition to entry by a team, a notification to area supervision of entry time and estimated duration of work is usually required, along with notification to supervision when the team leaves the area.

d. Safety equipment. Personnel performing maintenance on site utility systems should use the following personal safety equipment. This listing describes safety equipment required to perform routine maintenance for a facility and facility systems operating in a non-emergency condition. A description of the protective equipment and isolation and decontamination procedures for working in contaminated areas is beyond the scope of this manual.

(1) Long-sleeve coveralls (100% cotton)

(2) Safety shoes

(3) Safety glasses

(4) Gloves

(5) Flashlight

(6) Non-conducting hard hat

(7) Hearing protection in high noise areas

(8) Respiratory protection as required by site conditions

(9) When making initial openings into systems which are or recently have been under pressure, a full face shield and rain suit are required.

(10) Additional maintenance safety equipment should be available at the site for use in performing larger scheduled maintenance projects. Such equipment may include safety harnesses, ropes, ladders, gas masks, welding safety equipment, safety lamps, toxic gas and oxygen-deficiency indicators, and explosimeters.

e. Safe work practices. The following is a listing of safe work practices which apply primarily to the maintenance of mechanical systems. Special practices to be observed in working with electrical equipment are described in paragraph 2-8.

(1) Keep tools clean and properly stored.

(2) Remove items of clothing and jewelry such as ties, rings, wristwatches, and neck chains which could be caught in equipment being inspected or serviced.

(3) Do not bypass any alarm or safety system, unless maintenance instructions specifically call for such actions.

(4) Do not operate switches, push buttons, or any disconnect when equipment or circuits are tagged or locked out.

(5) Do not wipe down or attempt to service equipment in motion or in the vicinity of moving parts.

(6) Always ensure that guards are in place before operating equipment. Report missing guards to supervisors.

(7) Provide for periodic independent inspections by qualified inspectors for boilers, personnel elevators, and other such equipment.

(8) Provide for continuing maintenance and periodic proof testing of mechanical lifting equipment and slings.

(9) Avoid angled lifts when using mobile cranes or overhead crane systems.

(10) Follow the abrasive product manufacturer's recommendations with regard to the storage, handling, mounting, and use of abrasive grinding wheels.

(11) Weld only where there is adequate ventilation and the area is free of combustible material. Make sure the equipment used is in good condition and in the case of electric arc welding, make sure that both the welder and the work being welded are adequately grounded. Wear proper protective clothing and

adequate specialized eye protection. Do not weld galvanized or other coated metals without taking the correct precautions.

(12) Do not use compressed air for cleaning clothing or equipment and never point a stream of compressed air at a coworker.

(13) Wear protective clothing and personal protective equipment when working with hazardous chemicals.

2-8. Electrical safety

Any work done on or near electrical equipment of any kind should be considered dangerous and proper safety precautions must be taken. Personnel performing such work must be familiar with and observe all safety precautions. The basic safety rules to follow when dealing with electrical system equipment are as follows.

a. Electrical equipment. Consider all electrical equipment to be energized until it is known positively to be de-energized. Further, even after de-energization of electrical equipment, voltages may still exist and these voltages may be sufficient to cause death. Therefore, voltage tests should be performed and the voltages dissipated before proceeding with planned maintenance work.

b. Electrical work. Work to be done on energized lines and equipment must be done only by personnel qualified for that voltage classification. All tools and equipment used in such work must be maintained in proper operating order and should be periodically tested for compliance with all safety requirements.

c. Equipment-specific requirements. Technical manuals furnished with electrical equipment/systems should be consulted for specific safety requirements.

d. Safety watch. All maintenance should be performed with a minimum of one individual on a standby basis to react to an emergency situation should one occur.

e. Emergency lighting. Emergency lighting should be installed and maintained in equipment areas.

f. Safety board. A safety board with the following equipment should be located in a convenient location near electrical equipment to be serviced.

(1) Telephone with emergency numbers indicated

(2) First aid kit

(3) Flashlight

(4) Fire extinguisher

(5) Insulated hook stick

(6) Grounding cables

(7) Insulating blankets

(8) Insulating gloves

(9) Spill containment materials

(10) Hazardous gas analyzer (manhole testing)

(11) Rubber gloves

(12) Rubber apron

(13) Safety goggles

(14) Face protection

(15) Rubber mat

CHAPTER 3

DIESEL ENGINES

3-1. Minimum maintenance activities for diesel engines

The tables located at the end of this chapter indicate items that must be performed to maintain the diesel engines at a minimum level of operational readiness. Due to the many variations in engine age and design that may be encountered, not all of the items listed will be applicable for all facilities. All maintenance must be performed in accordance with the engine manufacturer's published maintenance schedule and procedures for the specific engine installed. Maintenance actions are included in this chapter for various modes of operation, subsystems, or components. Table 3-1 provides maintenance information for diesel engines in standby mode. Table 3-2 provides maintenance information for diesel engines operating in short-term activities. Short-term activities are those scheduled maintenance activities with a frequency of 1,000 hours run time or less. Table 3-3 provides maintenance information for diesel engines operation in long term activities. Long-term activities are those scheduled maintenance activities with a frequency greater than 1,000 hours run time.

3-2. Major equipment maintenance for diesel engines

Any maintenance procedure that requires disassembly of the engine or removal of components is considered major maintenance. Personnel performing any of the major maintenance procedures listed in this chapter must be trained diesel engine mechanics. In addition, the timing of the maintenance schedule for major maintenance items can vary significantly based on the engine design and speed. All maintenance must be performed in accordance with the engine manufacturer's published maintenance schedule and procedures for the specific engine installed.

3-3. Diesel engine performance trend analysis

Trend analysis is a valuable tool in predicting maintenance requirements and shall be used to determine impending problems and to schedule maintenance. Trend analysis consists of recording significant operating data and plotting that data versus engine hours and then analyzing the graphs for significant changes in performance. Operating data should be obtained under the same load and general operating conditions each time it is recorded. Data shall be taken at intervals not to exceed 250 hours (100 hours is preferred). Any significant change in recorded data should be verified by obtaining a second set of data. Various commercial software packages are available to aid in the planning of maintenance and analysis of malfunctions. These systems use field instrumentation to constantly monitor the status of the engine health. By storing this monitored data in a database during periods of normal operation, the system can identify changes in the operating behavior of the engine over long periods of time. Necessary adjustments and maintenance work can thus be planned on the basis of the engine condition. As a minimum, the following data shall be obtained and plotted.

a. Cylinder compression pressures

b. Cylinder firing pressures

c. Fuel pump/injector rack or governor power piston position

d. Cylinder exhaust temperature

e. Crankcase pressure (or vacuum)

f. Lube oil pressure at engine inlet or header

g. Air inlet manifold pressure

h. Lube oil added to engine sump in the last 100 hours. Do not include oil changes.

i. Lube oil analysis results, especially for trace metals

Table 3-1. Diesel engine – standby mode

Diesel Engine – Standby Mode	
Action	***Frequency***
WARNING! THE MAINTENANCE PROCEDURES OUTLINED IN THIS SECTION MAY OR MAY NOT REQUIRE REMOVING AN ENGINE FROM ITS READY STANDBY STATE SO THAT THE ENGINE DOES NOT AUTOMATICALLY START IF A POWER FAILURE OCCURS. WHEN NECESSARY, OBTAIN CLEARANCE FROM OPERATOR AND VERIFY THAT CONTROLS AND ENGINE STARTING DEVICES ARE PROPERLY LOCKED OUT TO PREVENT POSSIBLE AUTOMATIC STARTUP OF ENGINE.	
Check and verify operation of pre-lube pump.	8 hrs
Check and verify operation of keep warm system.	8 hrs
Check and verify operation of starting air compressors or battery charger.	8 hrs
Check and verify starting air pressure is correct or batteries are charged.	8 hrs
Verify that control power is available to the control system and all controls are in the proper position to allow automatic starting of the engines.	8 hrs
Check for fuel oil and lube oil leaks.	8 hrs
Check for cooling leaks.	8 hrs
Check day tank area for leaks.	8 hrs
Check lube oil level; add if required.	week
Inspect air filter; clean/replace if required.	week
Check starting air lubricator; fill if required.	week
Check oil level in governor; add if required.	week
Check coolant level in expansion tank.	week
Record and report any discrepancies.	week

Table 3-2. Diesel engine – operating mode, short term activities

Diesel Engine – Operating Mode, Short Term Activities	
Action	***Frequency***
WARNING! THE MAINTENANCE PROCEDURES OUTLINED IN THIS SECTION MAY OR MAY NOT REQUIRE REMOVING AN ENGINE FROM ITS READY STANDBY STATE SO THAT THE ENGINE DOES NOT AUTOMATICALLY START IF A POWER FAILURE OCCURS. WHEN NECESSARY, OBTAIN CLEARANCE FROM OPERATOR AND VERIFY THAT CONTROLS AND ENGINE STARTING DEVICES ARE PROPERLY LOCKED OUT TO PREVENT POSSIBLE AUTOMATIC STARTUP OF ENGINE.	
Inspect engine and listen for any unusual noise. Check for fuel oil, lube oil, and coolant leaks.	hr
Note and record any excessive vibration in the turbocharger or blower.	hr
Check and record the data indicated on the engine instrument panel. Note any unusual readings and investigate.	hr
Check lube oil level in engine crankcase or sump.	8 hrs
Check coolant level in expansion tank.	8 hrs
Check oil level in governor.	8 hrs
Check fuel strainers for water; drain if required.	8 hrs
Check fuel level in day tank	8 hrs
Check color and smoke level of exhaust gas.	8 hrs
Check lube oil and fuel filter pressure drop; change filters as required.	day
Inspect air filters; replace as required.	day
Check pH of engine coolant; add conditioner as required to meet manufacturer's recommendations.	250 hrs[1]
Take lube oil sample for test and analysis; change lube oil if indicated by test results or provide additives if recommended by lube oil supplier.	250 hrs[1]
Verify proper operation of all safety shutdown controls and alarms; immediately repair any defective items.	1K hrs[2]
Change fuel oil filters; filters should be changed based on maximum recommended pressure differential.	1K hrs[2]

Table 3-2. Diesel engine – operating mode, short term activities (continued)

Diesel Engine – Operating Mode, Short Term Activities	
Action	***Frequency***
Clean and inspect centrifugal lube oil filters if provided.	1K hrs[2]
Grease/lubricate auxiliary pump bearings.	1K hrs[2]

[1]Every Month for Standby Units
[2]Every Six Months for Standby Units

Table 3-3. Diesel engine – operating mode, long term activities

Diesel Engine – Operating Mode, Long Term Activities	
Action	***Frequency***
WARNING! THE MAINTENANCE PROCEDURES OUTLINED IN THIS SECTION MAY OR MAY NOT REQUIRE REMOVING AN ENGINE FROM ITS READY STANDBY STATE SO THAT THE ENGINE DOES NOT AUTOMATICALLY START IF A POWER FAILURE OCCURS. WHEN NECESSARY, OBTAIN CLEARANCE FROM OPERATOR AND VERIFY THAT CONTROLS AND ENGINE STARTING DEVICES ARE PROPERLY LOCKED OUT TO PREVENT POSSIBLE AUTOMATIC STARTUP OF ENGINE.	
Inspect valves and check valve clearance; adjust as required. On two-cycle engines, inspect and clean inlet and exhaust ports.	2K hrs
Check injector timing; adjust as required.	2K hrs
Verify proper operation of all instrumentation.	2K hrs
Inspect blower drive and timing gears if applicable.	2K hrs
Inspect aftercooler; clean if required.	4K hrs
Inspect and clean turbocharger if required.	4K hrs
Change governor oil.	4K hrs
On two-cycle engines, inspect pistons, rings, inlet and exhaust ports, and cylinder liner.	4K hrs
Remove and inspect one cylinder head, piston, liner, and connecting rod. Measure all surfaces subject to wear, and record data for use in determining overhaul intervals. Inspect all oil passages and water side surfaces for obstructions and deposits.	8K hrs
Check foundation bolts for tightness. Where engine and driven equipment are mounted on a skid with spring isolators, inspect spring isolators for proper clearance.	8K hrs
Drain and flush cooling system. Replace coolant. Inspect all thermostatic valves or regulators.	8K hrs
Inspect all engine-driven pumps.	8K hrs
Inspect aftercooler and lube oil cooler; clean if required.	8K hrs
Inspect all gears and/or chain drives for driven components and auxiliaries for wear; adjust if appropriate.	8K hrs
Check alignment of engine and driven equipment.	8K hrs

CHAPTER 4

GAS TURBINES

4-1. Minimum maintenance activities for gas turbines

The tables located at the end of this chapter indicate items that must be performed to maintain the gas turbines at a minimum level of operational readiness. Due to the many variations in engine age and design that may be encountered, not all of the items listed will be applicable for all facilities. In addition, the timing of the maintenance schedule for major maintenance items can vary significantly based on the engine design and operating conditions. All maintenance must be performed in accordance with the engine manufacturer's published maintenance schedule and procedures for the specific engine installed. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 4-1 provides maintenance information for gas turbines in standby mode. Table 4-2 provides maintenance information for gas turbines operating in short-term activities. Short-term activities are those scheduled maintenance activities with a frequency of 1,000 hours run time or less. Table 4-3 provides maintenance information for gas turbines operating in long-term activities. Long-term activities are those scheduled maintenance activities with a frequency greater than 1,000 hours run time.

4-2. Major equipment maintenance for gas turbines

Any maintenance that requires disassembly of the gas turbine is considered major maintenance. Personnel performing any of the major maintenance procedures listed in this chapter must be trained turbine engine mechanics. All maintenance must be performed in accordance with manufacturer's published maintenance procedures for the specific gas turbine installed.

a. Turbine engine overhaul. Overhaul of gas turbine engines should be based on readily detectable deterioration in performance of the unit. The following symptoms indicate the need for major maintenance.

(1) Continuously increasing exhaust temperatures

(2) Severe fouling of compressor blades

(3) Severe deposits on or deterioration of turbine blades and/or guide vanes

(4) Large particles on magnetic plugs

(5) Severe vibration

(6) Gradually decreasing runout time at engine shutdown

b. Maintenance support. The technical requirements for maintaining gas turbines are frequently beyond the capabilities of the staff at most facilities. For this reason, the option of contracting major maintenance from the manufacturer is both practical and economical. The manufacturer can provide trained staff on short notice to make needed repairs. The entire replacement of the engine can usually be accomplished in less than a day. This is based on having needed components on hand at the facility. Remote sites that are not easily accessible may not be able to exercise this option and must have personnel onsite trained to perform major maintenance.

4-3. Gas turbine performance trend analysis

Trend analysis is a valuable tool in predicting maintenance requirements and shall be used to determine impending problems and to schedule maintenance. Trend analysis consists of recording significant operating data and plotting that data versus engine hours and then analyzing the graphs for significant changes in performance. Operating data should be obtained under the same load and general operating conditions each time it is recorded. Data shall be taken at intervals not to exceed 250 hours (100 hours is preferred). Any significant change in recorded data should be verified by obtaining a second set of data. Various commercial software packages are available to aid in the planning of maintenance and analysis of malfunctions. These systems use field instrumentation to constantly monitor the status of the engine health. By storing this monitored data in a database during periods of normal operation, the system can identify changes in the operating behavior of the engine over long periods of time. Necessary adjustments and maintenance work can thus be planned on the basis of the engine condition. As a minimum, the following data shall be obtained and plotted.

a. Ambient temperature

b. Compressor discharge temperature

c. Exhaust temperature

d. Lube oil supply temperature

e. Lube oil return temperature

f. Inlet air pressure (downstream of filters)

g. Compressor discharge pressure

h. Exhaust pressure

i. Fuel pressure (before and after start)

j. Lube oil pressure (before and after filter)

k. Fuel consumption

l. Lube oil consumption

m. Governor rack or metering valve position

n. Lube oil analysis results, especially for trace metals

Table 4-1. Gas turbine – standby mode

Gas Turbine – Standby Mode	
Action	***Frequency***
WARNING! MAINTENANCE PROCEDURES OUTLINED IN THIS SECTION MAY OR MAY NOT REQUIRE REMOVING AN ENGINE FROM ITS READY STANDBY STATE SO THAT THE ENGINE DOES NOT AUTOMATICALLY START IF A POWER FAILURE OCCURS. WHEN NECESSARY, OBTAIN CLEARANCE FROM OPERATOR AND VERIFY THAT CONTROLS AND ENGINE STARTING DEVICES ARE PROPERLY LOCKED OUT TO PREVENT POSSIBLE AUTOMATIC STARTUP OF ENGINE.	
Check and verify operation of pre-lube pump.	8 hrs
Check and verify operation of lube oil heating system.	8 hrs
Check and verify operation of starting air compressors, battery charger, or other starting system components.	8 hrs
Check and verify starting air pressure is correct, batteries are charged, and all other starting system components are in ready-to-start condition.	8 hrs
Verify that control power is available to the control system and all controls are in the proper position to allow automatic starting of the engines.	8 hrs
Check for any oil leaks.	8 hrs
Check for coolant leaks.	8 hrs
Check the day tank area for fuel leaks.	8 hrs
Check lube oil level, add if required.	week
Inspect air filter. Clean/replace if required.	week
Check starting air lubricator. Fill if required. Check level of hydraulic fluid in reservoir on hydraulic starting systems.	week
Check oil level in governor, add if required.	week
Record and report any discrepancies.	week

Table 4-2. Gas turbine – operating mode, short term activities

Gas Turbine – Operating Mode, Short Term Activities	
Action	***Frequency***
WARNING! THE MAINTENANCE PROCEDURES OUTLINED IN THIS SECTION MAY OR MAY NOT REQUIRE REMOVING AN ENGINE FROM ITS READY STANDBY STATE SO THAT THE ENGINE DOES NOT AUTOMATICALLY START IF A POWER FAILURE OCCURS. WHEN NECESSARY, OBTAIN CLEARANCE FROM OPERATOR AND VERIFY THAT CONTROLS AND ENGINE STARTING DEVICES ARE PROPERLY LOCKED OUT TO PREVENT POSSIBLE AUTOMATIC STARTUP OF ENGINE.	
Inspect engine and listen for any unusual noise. Check for fuel oil and lube oil leaks.	hr
Note and record any excessive vibration.	hr
Check and record the data indicated on the engine instrument panel. Note any unusual readings and investigate.	hr
Check lube oil level in sump (Also check level in reduction gear if it is a separate system).	8 hrs
Check oil level in governor.	8 hrs
Check fuel strainers for water and drain if required.	8 hrs
Check day tank level.	8 hrs
Check lube oil and fuel filter pressure drop and change filters as required.	day
Inspect air filters and replace as required.	day
Inspect exterior of engine and auxiliary components for broken lock wires, loose nuts or bolts, and general security of installation.	250 hrs[1]
Check control linkage for freedom of movement, wear, and tightness of connections.	250 hrs[1]
Check for unusual noises in gears, bearings, couplings, and pumps.	250 hrs[1]
Check for excessive vibration of couplings, shaft extensions, and housing.	250 hrs[1]
Remove and inspect magnetic plugs for accumulation of metal particles. Also perform continuity check.	250 hrs[1]
Check operation and calibrate speed and temperature control system.	250 hrs[2]

Table 4-2. Gas turbine – operating mode, short term activities (continued)

Gas Turbine – Operating Mode, Short Term Activities	
Action	***Frequency***
Inspect engine mounts for cracks or decrease in vibration isolation.	500 hrs[3]
Inspect electrical harness leads and cables for cracks or other signs of wear.	500 hrs[3]
Check fuel manifold drain valve for proper operation.	500 hrs[3]
Inspect igniters and liner supports.	500 hrs[4]
Inspect fuel nozzles for carbon or other damage. If one or more nozzles need replacement, replace full set. If contamination is found, replace high pressure fuel filter.	500 hrs[4]
Inspect first stage turbine blades and vanes.	500 hrs[4]
Inspect combustion liners.	500 hrs[4]
Inspect thermocouples and wiring.	500 hrs[4]
Check contact pattern of reduction gear teeth.	500 hrs[4]
Verify proper operation of all safety shutdown controls and alarms. Immediately repair any defective items.	1K hrs[3]
Inspect bleed valves. Check valves for air leaks.	1K hrs[3]
Inspect engine inlet and compressor assembly.	1K hrs[3]
Grease/lubricate auxiliary pump bearings.	1K hrs[3]
Clean breather element on reduction gear.	1K hrs[3]
Inspect igniters and liner supports.	1K hrs[5]
Inspect fuel nozzles for carbon or other damage. If one or more nozzles need replacement, replace full set. If contamination is found, replace high pressure fuel filter.	1K hrs[5]
Inspect first stage turbine blades and vanes.	1K hrs[5]
Inspect combustion liners.	1K hrs[5]
Inspect thermocouples and wiring.	1K hrs[5]

[1] Monthly for Standby Units.
[2] Perform at the first 250 hours.
[3] Every 6 months for Standby.
[4] Perform at the first 500 hours.
[5] Perform at the first 1000 hours.

Table 4-3. Gas turbine – operating mode, long term activities

Gas Turbine – Operating Mode, Long Term Activities	
Action	***Frequency***
WARNING! THE MAINTENANCE PROCEDURES OUTLINED IN THIS SECTION MAY OR MAY NOT REQUIRE REMOVING AN ENGINE FROM ITS READY STANDBY STATE SO THAT THE ENGINE DOES NOT AUTOMATICALLY START IF A POWER FAILURE OCCURS. WHEN NECESSARY, OBTAIN CLEARANCE FROM OPERATOR AND VERIFY THAT CONTROLS AND ENGINE STARTING DEVICES ARE PROPERLY LOCKED OUT TO PREVENT POSSIBLE AUTOMATIC STARTUP OF ENGINE.	
Inspect igniters and liner supports.	2K hrs[1]
Inspect fuel nozzles for carbon or other damage. If one or more nozzles need replacement, replace full set. If contamination is found, replace high pressure fuel filter.	2K hrs[1]
Inspect first stage turbine blades and vanes.	2K hrs[1]
Inspect combustion liners.	2K hrs[1]
Inspect thermocouples and wiring.	2K hrs[1]
Check operation and calibrate speed and temperature control system.	2K hrs[1]
Take lube oil sample for test and analysis; change lube oil if indicated by test results.	4K hrs[2]
Replace lube oil filter; filter should be replaced based on maximum recommended pressure differential.	4K hrs[2]
Check reduction gear tooth wear.	4K hrs[2]
Replace low and high pressure fuel filters; filters should be replaced based on maximum recommended pressure differential.	8K hrs[2]
Inspect fuel nozzles.	8K hrs[2]
Check the following items on the reduction gear; tooth pattern and wear, bearing clearances, end play, and alignment. Check lube oil spray nozzles and internal tubing.	8K hrs[2]
Calibrate all instrumentation.	8K hrs[2]

[1] Every 9 months for Standby.
[2] Every 12 months for Standby.

CHAPTER 5

FUEL OIL SYSTEMS

5-1. Minimum maintenance activities for fuel oil systems

The tables located at the end of this chapter indicate items which must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter for various modes of operation, subsystems, or components are summarized in table 5-1, Fuel Oil System.

5-2. General maintenance procedures for fuel oil systems

This section presents general instructions for maintaining the types of components associated with fuel oil systems.

a. Inspect fuel oil system. Start at the outdoor fuel oil storage tanks and follow the fuel oil system piping all the way to the diesel engine-generators. Inspect for the following.

(1) Leaking pipe joints and/or corrosion

(2) Missing identification tags on system valves and components

(3) Sagging or misalignment of piping

(4) Fuel oil leaks or spills. Inspect containment area for the storage tanks for cracks or any other inconsistencies.

b. Exercise valves. Exercise all valves in the fuel oil system.

(1) Inspect packing gland and tighten if necessary.

(2) Check for correct positioning and operation.

(3) Check for leaking seals.

(4) Adjust operator linkages and limit switches on control valves.

c. Clean strainer. Change strainer basket by turning change valve handle to isolate one of the baskets from service. Remove cover and basket screen. Clean and reinstall screen in strainer in same position as before and tighten cap. Place cleaned basket in service by turning the change valve handle. Clean other basket screen.

d. Replace filter elements. Replace coalescing filter elements when differential pressure has increased above design standard. Follow manufacturer's instructions for filter element replacement.

e. Check fuel levels. Check the level of fuel oil in each storage tank. Check these levels from the central control console and from each tank mounted level indicator. Fill the storage tanks as required.

f. Check level controls. Check the operation of level controllers by draining fuel oil from the day tanks. Allow the fuel oil transfer pumps to start and stop automatically. Note the level in the day tanks at which the pump starts and stops, and the respective control opens and closes. This procedure should be done on one day tank at a time.

g. Test alarms. Verify that the horns sound and all annunciator lights illuminate by pressing the appropriate test push buttons. Press the ACKNOWLEDGE and RESET push buttons when proper operation has been confirmed.

h. Check tank heaters. Verify that all fuel oil heaters are operating correctly.

i. Dewater day tanks. Drain water and sediment from day tanks by momentarily opening drain valve to flush out these contaminants.

j. Lubricate rotating equipment. Grease all zerks at the manufacturer-recommended service interval. Grease gently with a handgun to avoid damage to grease seals. Do not overgrease.

(1) Ball or roller bearings tend to heat up when overgreased and will cool down to normal running temperatures when the excess grease either oozes out or is wiped off. The normal operating temperature of a bearing may be well above 140°F, which is "hot" to touch. Temperatures should be checked with a thermometer and any temperature readings over 180°F should be questioned. If a drop of water placed on a bearing sizzles, the bearing is in distress and should be changed before it seizes and ruins the shaft. For sleeve bearing assemblies with oil reservoirs, service reservoirs at manufacturer's recommended interval with recommended viscosity lubricating oil. Do not overfill reservoir as overheating may result. When new sleeve bearing units are placed in service, drain and flush the oil reservoir after about two weeks of operation and refill the reservoir with new lubricating oil of the proper viscosity.

(2) During equipment overhauls, bearing assemblies should be thoroughly cleaned, inspected, and adjusted in accordance with the manufacturer's recommendations. All old grease should be removed from bearings and the bearings repacked with grease a minimum of every two years. Monitor the operation of all recently installed bearings. Check for overheating (alignment, lubrication), vibration (alignment), loose collars, fasteners, etc. Early problem detection can avoid early failure and costly replacement.

k. Packing adjustment. Occasional packing adjustment may be required to keep leakage to a slight weep; if impossible to reduce leakage by gentle tightening, replace packing. A slight weeping through the packing gland is required so that the process fluid provides lubrication for the packing material. Maintain a supply of the recommended type and size of packing required for the equipment. Do not substitute one type of packing with another without verifying the packing types are compatible. Do not use oversized packing. If diameter of oversized packing is reduced by hammering, early failure of packing may result. A too tight packing joint may interfere with equipment operation, can damage equipment, and, again, may result in early failure of the packing. A typical procedure for replacing common types of packing is as follows.

(1) Remove all old packing.

(2) Inspect shaft for wear and replace as required.

(3) Use proper sized packing and cut packing into rings using the shaft as a guide. When cutting to length, hold packing tightly around shaft but do not stretch packing. Cut with a butt joint. **Do not wind packing around shaft.**

(4) Thoroughly clean shaft and housing.

(5) Install one ring at a time. Oil or grease lubrication, if permitted, will assist when packing the ring into the box. Offset joints of each succeeding ring by at least 90 degrees from the previous ring.

(6) If shaft is equipped with a lantern ring, be sure that lantern ring is slightly behind lubrication hole in stuffing box; otherwise, the lantern ring will move forward when the gland is taken up and the packing behind the ring may plug the lubrication hole.

(7) Tighten the gland bolts all the way to seat the packing. Then loosen the nuts until the nuts are finger tight. In most applications, newly installed packing should be allowed to leak freely on startup. After startup, tighten packing gland until only 2 to 3 drops a second are leaking. **Do not try to stop leakage entirely.** The leakage lubricates the packing and prevents early failure of the packing and shaft.

l. Mechanical seals. There are many different mechanical seal designs. As a result, there are no standard procedures for maintaining and installing mechanical seals. Mechanical seal installations commonly fail because the seal was not placed in the correct position. Seal faces may wear rapidly resulting in early seal failure if the spring has too much initial compression. This results in too much force between the faces of the seal which does not allow proper lubrication of the surfaces. Alternatively, if the spring has too little initial compression, the seal faces will separate at normal operating pressures and leak. It is important that manufacturer's information for the seals used be obtained and closely followed. In general, there are four critical requirements in any seal installation as follows.

(1) Determine that the equipment is ready to have the seal installed, shaft and seal housing have been inspected and repaired as required, and components have been thoroughly cleaned.

(2) Place the seal in the correct position for the right operating length (consult manufacturer's data).

(3) Prevent damage to seal rings.

(4) Prevent damage to seal faces.

m. Transfer pump end clearance adjustment. After long service, the running clearance between the end of the rotor teeth and the head may increase to the point where the pump is losing capacity or pressure. Resetting the end clearance will normally improve pump performance. Refer to the manufacturer's Technical Service Manual.

n. Examine internal pump parts. Periodically, remove the head and examine idler bushing and head and pin for wear. Replacing a relatively inexpensive idler bushing and idler pin after only moderate wear will eliminate the need to replace more expensive parts at a later date.

o. Clean all equipment. Clean all equipment regularly. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

p. Clean flame arresters. Disassemble the flame arrester and clean dirt and dust from plates and surfaces. Use extreme caution when working around fuel oil vapors. Reassemble the arrester.

q. Inspect engine fuel oil components. Inspect diesel engine mounted fuel oil system components daily. Check for leaks or any inconsistencies.

r. Dewater strainers and filters. Drain water from primary strainer and secondary fuel oil filters daily by momentarily opening drain valves to flush out sediment and water.

s. Inspect fuel oil cooler. Clean coils and check proper setting and operation of thermostats.

t. Flexible coupling installation and alignment. These instructions cover, in general, the installation of flexible couplings of the pin, gear, or grid types.

(*1*) Verify that equipment the coupling is serving is completely assembled and adjusted before installing drive coupling.

(2) Install each half cover with seals on its shaft. Consult coupling manufacturer's data to determine proper orientation of long and short shanks of coupling.

(3) For non-taper lock hub units, heat coupling to approximately 300°F by means of a hot oil bath or oven. **Do not apply flame to hub teeth.**

(4) Install coupling hubs on motor and driven shafts. Install shaft keys while hubs are still hot. Face of hub should be flush with end of shaft.

(5) Adjust clearance between the coupling faces. Consult manufacturer's data for proper clearance. (Some coupling units may have required clearance stamped on coupling unit.)

(6) When a sleeve bearing motor is used, locate motor so that when the motor rotor is closest to the driven shaft, the motor shaft will not touch the driven shaft. If the motor shaft has a magnetic center marked, base clearance between coupling faces on magnetic center. Otherwise, determine maximum motor shaft movement and base clearance between coupling faces on one half the motor shaft movement.

(7) With tapered wedge, feeler gauges, or dial indicator, verify that faces of coupling hubs are parallel.

(8) Using a straightedge or dial indicator, verify that motor and driven shafts are parallel. Shim and adjust as required.

(9) After alignment of shafts is obtained, recheck spacing between hub faces and verify that faces are parallel to within 0.001 inch.

(10) When alignment is complete, thoroughly clean both sides of the coupling and inspect all parts for damage. Install the gasket and draw the coupling flanges together keeping gasket holes in line with bolt holes. Insert and tighten bolts, lock washers and nuts. Lubricate coupling in accordance with manufacturer's data. When aligning shafts, a general rule is to align large motor shafts so the center of the motor shaft is 0.001 inch lower than the driven shaft for each 1 inch of motor shaft diameter. Turbine shafts or similar large rotating equipment as a general rule are set 0.001 inch lower than the driven shaft for each 1 inch of height from the mounting feet to the center of the shaft. This initial offset provides for thermal expansion of the equipment. After the equipment has been in operation long enough to reach operating temperature, the alignment of the shafts should be checked and adjusted as required.

Table 5-1. Fuel oil system

Fuel Oil System	
Action	***Frequency***
Inspect engine fuel oil components.	day
Dewater strainers and filters.	day
Check fuel level gauges.	day
Manually check fuel level.	week
Inspect fuel oil system.	mo
Exercise valves.	mo
Exercise fuel circulation system.	mo
Clean strainers.	mo
Replace filter elements.	mo
Check level controls.	mo
Test alarms.	mo
Check tank heaters.	mo
Dewater fuel tanks.	mo
Circulate day tank to main holding tank.	mo
Clean all pumps.	mo
Inspect fuel oil coolers.	mo
Transfer pump packing adjustment.	2/yrs
Clean flame arrester.	2/yrs
Transfer pump end clearance adjustment.	yr
Examine internal pump parts.	yr
Pressure gauges.	yr
Temperature indicators.	yr
Lubricate transfer pumps.	6/yrs
Inspect and clean fuel tanks.	3 mos
Paint fuel tanks.	as required

CHAPTER 6

LUBE OIL SYSTEMS

6-1. Minimum maintenance activities for lube oil systems

The tables located at the end of this chapter indicate items which must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. These should be used to develop a comprehensive maintenance plan for the facility. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 6-1 provides maintenance information for diesel engine lube oil systems in standby mode. Table 6-2 provides maintenance information for diesel engine lube oil systems in operating mode. Table 6-3 provides maintenance information for central lube oil storage dispensing systems. Table 6-4 provides maintenance information for lube oil instrumentation and electrical systems.

6-2. General maintenance procedures for lube oil systems

This section presents general instructions for maintaining the types of components associated with lube oil systems.

a. Oil testing. Oil testing is performed to verify the quality of oil delivered to a facility. In-service testing is performed to determine the condition of the oil, and the test results are used to determine the level of oil maintenance required, conditioning, additive addition, partial replacement, or full replacement. It is always important to use the same test procedure. As shown in listing of consensus standard organization tests for characterizing oils, there are often several different test methods available to quantify a particular characteristic of the oil. The answers provided by different test methods on the same oil sample for a particular parameter may not be the same. Maintaining accurate records of tests is important. The results from a single test usually have no meaning by themselves. Test results usually only have meaning by indicating changes since previous tests.

(1) A supplier should provide certified documentation prior to or with the lube oil delivery verifying that the oil has been tested in accordance with the Army Oil Analysis Program and meets the specifications for the lube oil used by the facility. If documentation is not provided for the lube oil, the facility should sample and analyze the lube oil prior to use. The facility should take samples of all lube oil delivered to the facility and retain the samples until that lot of lube oil is used. Even if certified test reports are provided by the supplier, the facility should periodically have independent analyses performed to ensure compliance with purchase order or contract requirements.

(2) The lube oil change or conditioning interval may be determined by oil analysis as recommended by the diesel engine manufacturer. Proper lube oil sampling is critical to ensure long engine life. Facilities that develop and follow a sampling program which triggers follow-up lube oil conditioning may never have to change the full volume of lube oil from an engine sump. Consideration should be given to utilizing the Army Oil Analysis Program (AOAP) lube oil testing laboratories for analyses of samples taken.

(a) Samples must be taken and analyzed at regularly scheduled intervals. The operator should also record the number of hours that the engine has been operated and the number of operating hours

since the last lube oil conditioning or change cycle. It is very important for the operator to develop an accurate history of each engine. By doing so, samples can be compared over time so that any changes in oil properties can be detected.

(b) The result of oil analyses can show wear on metal. These results can be used to determine when the oil needs conditioning or replacing and whether an engine or one of its support systems is developing problems that must be remedied. A high iron level usually indicates cylinder liner wear. High chromium indicates piston ring wear. High aluminum indicates piston and/or bearing wear. High silicone indicates dirt which may indicate a damaged intake air filter and/or a leak in the engine air intake duct system. High copper can indicate bearing wear. If all of the preceding element levels are high, except for silicone, this may indicate acid attack due to overcooling which can result from running the engine with little or no load.

(c) Running under no load increases the buildup of carbon in the lube oil because this overcooled condition causes increased acid and soot buildup in the oil. As a result, the lube oil conditioning or change interval will vary a great deal and will depend on how the engines are operated (loaded or unloaded) and the frequency operation. For emergency service diesel engines, if engines are operated and loaded at least once a month for a few hours (preferred engine exercise interval), samples from each engine should be taken during every other engine exercise cycle. However, if the engines are operated at less frequent intervals, lube oil samples should be taken every time the engines are operated.

(d) The engine lube oil for each engine should be sampled using new and clean individual sample bottles and sampling tubes for each engine. The contaminants must be suspended in the oil for samples to be accurate. Samples must be taken while engines are operating at normal operating temperature. Do not reuse sample bottles or tubing. While thorough lube oil evaluation requires a certified, well-equipped testing laboratory, a number of tests that can be performed at the facility which can provide good information are listed below. However, the value of these tests can be very dependent on the skill and experience of the person performing the tests, and having a database of results from the same tests over a long period of time.

(e) Measure viscosity measured using a commercially available instrument known as a "Visgage" (Federal Stock No. 6630-255-8057).

(f) Monitor relative soot and residue levels using a blotter test. Blotter test kits with comparison charts are commercially available. Soot indicated by color of spot made by oil drop while particulate content indicated by residue left on blotter surface.

(g) Monitor total contaminants by the centrifuge method [American Society for Testing and Materials (ASTM) D 91]. Requires laboratory centrifuge, graduated cone-shaped sampling bottles, and chemical reagents (naphtha). Percentage of total contaminants read off graduated scale on sampling bottles.

(h) Monitor the detergent capacity of the lube oil using a blotter test. Blotter test kits with comparison charts are commercially available. Size of oil spot on blotter indicates detergent capacity of lube oil.

b. Determine lube oil change interval. How often lubricating oil should be changed is difficult to answer because of many factors, including the make of the engine, the load condition (constant versus variable), atmospheric conditions, engine operating temperatures, etc.

(1) To establish an approximate frequency for a specific engine installation, the following procedure may be used.

(a) Operate the engine for 300 hours on new oil.

(b) Replace the oil with new oil and have the used oil analyzed.

(c) If the used oil is found to still be usable, increase the hours of operation before changing oil by 200 hours.

(d) Repeat steps *(b)* and *(c)* until the used oil analysis indicates that the used oil is unsatisfactory for further use.

(2) After the oil change period for an engine type operated at a specific facility has been determined, subsequent oil changes can be scheduled far in advance with a high degree of certainty. Nevertheless, the lube oil condition should be regularly tested to verify proper lube oil performance. Remember, if the engine operating conditions change (higher or lower operating temperatures, different loads, etc.), the oil change interval should be reevaluated.

c. Inspect lube oil system. Start at the main clean and dirty lube oil storage tanks and follow the lube oil system piping all the way to the points of end use. Inspect for the following.

(1) Leaking pipe joints and/or corrosion

(2) Missing identification tags on system valves and components

(3) Sagging or misalignment of piping

(4) Lube oil leaks or spills. Inspect containment area for the storage tanks for cracks or any other inconsistencies.

d. Exercise valves. Exercise all valves in the lube oil system.

(1) Inspect packing gland and tighten if necessary.

(2) Check for correct positioning and operation.

(3) Check for leaking seals.

(4) Adjust operator linkages and limit switches on control valves.

e. Test alarms. Verify that the horns sound and all annunciator lights illuminate by pressing the appropriate test push buttons. Press the ACKNOWLEDGE and RESET push buttons when proper operation has been confirmed.

f. Check tank heaters. Verify that all storage tank, piping, and equipment heaters are operating correctly.

g. Self-contained temperature control valves (thermostats). Remove the engine thermostat valve from the cooling system. Clean valve and inspect sliding valve for scoring or damage that prevents free movement or tight shutoff. Repair by gently lapping or replace components as necessary. Thoroughly

clean thermostat valve interior surfaces before reinstalling thermostat valve in engine cooling system. Verify valve operation as follows.

(1) Remove the element assembly from the valve and place in a bucket of water which is heated to 10°F below the temperature rating of the valve.

(2) Stir the water vigorously for about five minutes. The sliding valve should not be off the seat.

(3) Place the element assembly in a bucket of water which is heated to 15°F above the temperature rating of the valve.

(4) Stir the water vigorously for about five minutes. The sliding valve (and temperature element) should be fully stroked. Full stroke can be verified by placing the element assembly back into the valve housing and pushing the valve seat spider fully into the housing counterbore. If the spring action of the overtravel spring can be felt, the element is fully stroked. (This procedure must be done very rapidly.)

h. Transfer pump end clearance adjustment. After long service, the running clearance between the end of the rotor teeth and the head may increase to the point where the pump is losing capacity or pressure. Resetting the end clearance will normally improve pump performance. Refer to the manufacturer's technical service manual.

i. Examine internal pump parts. Periodically, remove the head and examine idler bushing and head and pin for wear. Replacing a relatively inexpensive idler bushing and idler pin after only moderate wear will eliminate the need to replace more expensive parts at a later date.

j. Clean all equipment. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

k. Inspect engine lube oil components. Inspect diesel engine mounted lube oil system components daily. Check for leaks or any inconsistencies.

Table 6-1. Diesel engine lube oil system – standby mode

Diesel Engine Lube Oil System– Standby Mode	
Action	***Frequency***
Prelube Pump	
Inspect prelube pump for normal operation and report any discrepancies as follows:	
Pump running.	8 hrs
Inspect and adjust packing glands and seals.	week
Inspect and adjust shaft coupling	week
Lubricate bearings.	3 mos
Lube Oil	
Check and record oil level.	week
Obtain oil sample for analysis as follows:	
Exercise engine and obtain samples after every second exercise.	mo
If the interval between engine exercises is more than 1 month, obtain sample after every exercise.	as req'd
Change lube oil as required by oil analysis.	as req'd

Table 6-2. Diesel engine lube oil system – operating mode

Diesel Engine Lube Oil System– Operating Mode	
Action	***Frequency***
Lube Oil	
Check level in lube oil sump. Log oil temperature and pressure readings.	hr
Tank lube oil sample and test fuel oil containment level.	week
Take lube oil sample for laboratory analysis. Monthly or after 250 hours of operation, whichever occurs first.	mo/250 hrs
Change lube oil (as indicated by laboratory analysis).	as req'd
Lube Oil Filter	
Check pressure drop.	shift
Change in service filter elements. As indicated by pressure drop, or after 1,000 hours of operation or every 3 months, whichever occurs first.	1K hrs/3 mos
Final Lube Oil Filter	
Check pressure drop.	shift
Change filter element. As indicated by pressure drop, or after 1,000 hours of operation or every 3 months, whichever occurs first.	1K hrs/3 mos

Table 6-3. Central lube oil storage and dispensing system

Central Lube Oil Storage & Dispensing System	
Action	***Frequency***
System	
Start at the lube oil storage tanks (clean and dirty) and follow the lube oil system to all final use points. Inspect for and report any discrepancies as follows:	
Leaking pipe joints.	day
Leaking heat exchangers.	day
Leaking around packing glands on valves and pumps.	day
Leaking gaskets on filter housings.	day
Excessive noise or unusual vibration from motors, pumps, and other rotating equipment.	day
Wipe oil and dirt from equipment and report all discrepancies to supervisor.	mo
Main Storage Tanks (Clean and Dirty)	
Check and record oil level.	week
Intermediate Storage Tanks (Clean and Dirty)	
Check and record oil level.	shift
Refill tank when level decreases to action level.	as req'd
Valves	
Exercise all valves and report all discrepancies to supervisor. Exercising valves shall include the following routine maintenance activities:	
Grease stems on OS&Y valves.	mo
Inspect packing gland and tighten if necessary.	mo
Check correct position and operation.	mo
Check for leaking seals.	mo
Pumps	
Lubricate bearings.	mo
Inspect and adjust packing glands. Replace as necessary.	mo
Inspect and adjust shaft coupling.	mo
Disassemble, rebuild and adjust mechanical elements in accordance with manufacturer's recommendations.	yr

Table 6-3. Central lube oil storage and dispensing system (continued)

Central Lube Oil Storage & Dispensing System	
Action	***Frequency***
Lube Oil Heaters	
Verify that heaters are operating.	mo
Strainers – Y-Type and Single Element Basket Type	
Clean strainer element.	mo
Controls	
Verify control function.	mo
Test alarms.	mo
Centrifuge	
Check gearbox lubricating oil level.	week
Grease sliding surfaces of bowl assembly.	3 mos
Clean operating water filters and desludgers.	3 mos
Change lubricating oil and clean gear chamber.	6 mos
Lubricate hand-operated parts such as lock screws.	6 mos
Clean dirty oil pump inlet filter.	6 mos
Disassemble self-cleaning bowls and clean all bores, nozzles, and chambers of the hydraulic system.	6 mos
Remove and inspect gaskets of bowl, and clean the grooves. Check for corrosion. Check if disk set is properly compressed.	6 mos
Check starting time and thickness of clutch linings.	6 mos
Check thickness of brake linings.	6 mos
Check rubber-metal bushing in neck bearing.	6 mos
Pack motor bearings.	yr
Remove bottom bearing and thoroughly clean all parts.	yr
Remove bowl and clean interior of upper frame.	yr
Inspect spindle bearings.	yr
Inspect worm gear drive.	yr
Check spindle speed.	yr

Table 6-4. Lube oil instrumentation and electrical

Lube Oil Instrume ntation & Electrical	
Action	***Frequency***
Level Gauges	
Check for accuracy. Remove manhole cover and check gauge reading against calibrated dipstick. Recalibrate as required following equipment manufacturer's instructions.	yr
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath.	yr
Pressure Gauges	
Isolate gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 7

ENGINE INTAKE AND EXHAUST SYSTEMS

7-1. Minimum maintenance activities for engine intake and exhaust systems

The tables that follow indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance for specific pieces of equipment. These should be used to develop a comprehensive maintenance plan for the facility. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 7-1 provides maintenance information for basic air intake and exhaust systems. Table 7-2 provides maintenance information for complex air intake and exhaust systems. Table 7-3 provides maintenance information for chemical, biological, and radiation (CBR) filter banks. Table 7-4 provides maintenance information for air intake and exhaust controls and instrumentation.

7-2. General maintenance procedures for engine intake and exhaust systems

This section presents general instructions for maintaining the types of components associated with engine intake and exhaust systems.

a. Intake air filter assembly. In this manual, the intake air filter assembly is considered to be a stand-alone filter unit, either mounted on or very close to the device being served. If the device being served is a diesel engine, gasoline engine, or any piece of rotating equipment, maintenance involving any disassembly of the intake air filter unit should not be performed while the engine is operating.

(1) Before removing filter elements, remove loose accumulations of dirt from face of filter and face of filter housing.

(2) After removing filter elements, wipe clean filter seating surfaces. For units with separate gaskets, replace gaskets at each filter change. Lubricate gasket or seal surfaces prior to installation as recommended by the equipment manufacturer.

(3) Carefully align new filter element in filter housing. Do not force filter elements, filter element hold-downs, or filter housing components into place.

(4) Lock filter elements and filter housing components into place as recommended by the manufacturer. Be sure all nuts, bolts, screws, and other fasteners are secure and cannot be sucked into the intake system.

b. Static element filter banks. Typical static element filter banks are made of a rectangular array of filter elements. Each individual filter element is usually mounted in a rectangular frame and can be comfortably handled by one person. The filter elements then either slide into the filter bank frame from the side or are snapped into the front or back of a holding frame which is part of the overall filter bank frame.

(1) Where a filter assembly is relatively small and is directly connected to a piece of rotating equipment, maintenance that requires the filter housing to be open so that intake air bypasses the filters

for a long period of time, or requires any disassembly of the filter housing should not be performed with the device being served in operation if possible. Large, walk-in filter assemblies may be maintained with the system in operation. When working in filter plenums, do not block doors between filter banks open.

(2) Accumulations of dirt between filter banks may indicate a hole in the filter housing, an improperly seated filter element, a damaged gasket or seal, or a damaged filter. When unusual accumulations of dirt are observed, determine the cause. Make any corrections possible at time of inspection; report problems that cannot be fixed on the spot for follow-up work. Vacuum plenums to remove accumulations of dirt. When replacing a filter element or changing out a filter bank:

(a) Before removing filter elements, remove loose accumulations of dirt from face of filter and face of filter housing.

(b) After removing filter elements, wipe clean filter seating surfaces. For units with separate gaskets, replace gaskets at each filter change. Lubricate gasket or seal surfaces prior to installation as recommended by the equipment manufacturer.

(c) Carefully align new filter element in filter housing. Do not force filter elements, filter element hold-downs, or filter housing components into place.

(d) Lock filter elements and filter housing components into place as recommended by the manufacturer. Be sure all nuts, bolts, screws, and other fasteners are secure and cannot be sucked into the intake system.

(e) Keep to a minimum the total number of filter elements removed at any one time when changing filter elements in an operating system.

c. Inspect air intake and exhaust system. Start at the air intake portal and follow the air intake and exhaust system to the exhaust portal. Inspect for:

(1) Obstructions to the air intake or exhaust portals

(2) Obstructions to the face area of filters

(3) Dirty filters (high pressure drop)

(4) Damage to or deterioration of filter housings, filters, fan housings, ducts, expansion joints, etc., that would allow unfiltered air into the system.

(5) Damage to or deterioration of exhaust ducts, expansion joints, silencers, etc., that would allow exhaust gases, or contaminants from other sources, to leak into occupied spaces.

(6) Obstructions in bypass dampers, isolation valves, and device operators that would prevent free movement of the device.

(7) Deformed expansion joints

(8) Misaligned or sagging duct sections

(9) Deformed or broken duct support devices. Verify that support devices designed to accommodate movement of the duct are free to operate.

(10) Unusual noise, vibration, or overheating

(11) Loose mechanical or electrical connections

(12) Missing components

(13) Low lube oil levels in equipment with lube oil sumps

(14) Misalignment of drives, worn belts and pulleys, and loose drive belts on belt-driven equipment

(15) Damaged or missing equipment guards

(16) Damaged or missing insulation

(17) Damaged or missing equipment tags

d. Exercise bypass dampers and isolation valves. Exercise all bypass dampers and exhaust system isolation valves in the air intake and exhaust system.

(1) Verify free operation of dampers and valves.

(2) Inspect any packing glands and tighten as necessary.

(3) Check for leaking seals.

(4) Wipe damper and valve operators clean, apply a light coat of protective oil to exposed operating shafts, and lubricate bearings and pinned connections.

(5) Adjust operator linkages for proper valve positioning, and adjust limit switches for proper position indication.

e. Test alarms. Verify operation of system alarms and alarm system by actuating appropriate system test push buttons. Verify that the audible alarm sounds and that all warning and annunciator lights operate.

f. Manometers. Inspect all manometers and service as required:

(1) For incline manometers, check manometer level and adjust as required.

(2) To zero manometers equipped with maintenance valve, turn valves to vent position, or if direct-connected, disconnect high- and low-pressure tubes. Loosen retaining screw on adjustable scale and slide scale until the zero mark is directly behind the fluid meniscus. Tighten retaining screw. Close vent valves, or reconnect high- and low- pressure reference tubes.

(3) If manometer fluid level is not within the scale adjustment range, add gauge fluid. Before adding fluid, set adjustable scale at approximate midpoint of range of adjustment. Verify that gauge fluid of the correct specific gravity has been obtained.

g. Belt drives. When belt replacement is required, replace multiple belts as a set. Loosen drive motor mounting, and slide motor toward driven shaft so that belts may be installed by laying belts onto pulleys. Do not lever belts onto pulleys, and ensure that belt covers are replaced after maintenance. Check belt tension several times during first 48 hours that new belts are in operation, and adjust belt tension as required.

(1) When belt tension adjustment is required, consult the belt manufacturer's literature for the proper tension force (and belt deflection to achieve that force). Deflect each belt at the midpoint between the pulleys to the deflection recommended, and read the belt tension. Adjust the tension as required. Many belts have an initial run-in period tension (usually about 48 hours) and then a broken-in tension. Generally, if the tension reading differs more than 2 pounds from the recommended reading, the belt tension should be adjusted. If a belt tension measuring device is not available, belt tension may be checked by observing the deflection when pressing down on each belt at about the midpoint between the pulleys. If the tension is correct, the belt deflection will be about one belt thickness for each 4 feet of center-to-center distance between the pulleys. Caution should be used in using this method because there are many different belt designs available for the same service, and each belt design may have different tension and deflection characteristics. To tension the belts, loosen the motor hold-down bolts. Move the motor away from the driven shaft to increase the tension and toward the driven shaft to decrease the tension. (If the motor is on a slide base, it will not be necessary to loosen the motor hold-down bolts. Adjustment is accomplished using the slide base positioning screw.) Tighten the motor hold-down bolts. Run the equipment for a short period of time, and then check the belt tension.

(2) When drive alignment is required, lay a straightedge across both the driver and driven pulleys. The straightedge should contact each pulley in two places. If the pulleys are not aligned, verify that the drive shaft and driven shaft are parallel. If the shafts are not parallel, adjust the motor so the shafts are parallel. When the shafts are parallel, adjust the positions of the pulleys on the shafts to achieve alignment. Verify that the driven pulley is in the correct position on the driven shaft and that the pulley is firmly locked in place. Loosen the pulley on the motor shaft, and move the pulley into alignment with the driven pulley. Tighten the pulley on the shaft, install and tension the drive belts, and run the equipment for a short period of time. Check drive alignment and adjust as required.

h. Fan clearance adjustment. After long service, the running clearances in some types of fans may increase to the point where the fan is losing capacity or pressure. Resetting the end clearance will normally improve fan performance. Refer to the manufacturer's technical service manual.

i. Examine internal parts of rotating equipment. Periodically, remove casing access covers and inspect components for wear. Replacing a relatively inexpensive part after only moderate wear can eliminate the need to replace more expensive parts at a later date.

j. Clean all equipment. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

k. Inspect rotating equipment. Inspect rotating components daily. Check for unusual noises or vibrations, and overheating or similar inconsistencies. Investigate any conditions that do not "feel" right.

Table 7-1. Basic air intake and exhaust systems

Basic Air Intake & Exhaust Systems	
Action	***Frequency***
NOTE! THIS TABLE APPLIES TO SYSTEMS WITH AN INTAKE AIR FILTER ASSEMBLY AND AN EXHAUST SILENCER EITHER MOUNTED ON THE ENGINE OR VERY CLOSE COUPLED (NO LONG SECTIONS OF INTAKE OR EXHAUST DUCT WITH A COMPLEX SUPPORT SYSTEM).	
Intake Air Filter Assembly	
Inspect and service as required. Inspection and servicing shall include the following:	
Verify that the air intakes are free of obstructions; remove obstructions as required.	day
Check the pressure drop across the filter elements (or the pressure in the engine air intake manifold) and clean or replace filter elements as required.	day
Exhaust Discharge Point	
Verify that the exhaust discharge point is free of obstructions; remove obstructions as required.	day
Overall Intake and Exhaust System	
Inspect all air intake and exhaust system piping and/or ducts and system components; report all discrepancies to supervision. Inspection shall include the following:	
Look for leaks and corrosion.	week
Look for visible cracks and/or deformation of expansion joints.	week
Look for broken and/or deformed system supports.	week
Look for damaged insulation.	week

Table 7-2. Complex air intake and exhaust systems

Complex Air Intake & Exhaust Systems	
Action	***Frequency***
NOTE! THIS TABLE APPLIES TO PARTICULATE REMOVAL SYSTEMS USING A SERIES OF FILTER BANKS WITH ARRAYS OF FILTER ELEMENTS. THE FILTER SYSTEMS MAY BE DUCTED DIRECTLY TO THE DEVICE BEING SERVED, MAY BE A STAND-ALONE UNIT FILTERING MAKEUP AIR INTO AN OCCUPIED SPACE, OR A COMBINATION OF MAKEUP INTO A SPACE AND DUCTED FROM THE SPACE TO THE ENGINE (OR DEVICE) USING COMBUSTION AIR. CBR FILTERS, WHICH ARE NOT PARTICULATE FILTERS, ARE COVERED ON A SEPARATE TABLE.	
Facility Air Intake and Exhaust Points	
Inspect intake and exhaust points for obstructions; remove obstructions as required.	week
Filter Assemblies	
Inspect filter assemblies and report all discrepancies to supervisor. Inspection shall include:	
Visually verify that all filters are properly installed; adjust as required.	week
Inspect each bank for large debris obstructing the flow of air through the bank; remove obstruction as required.	week
Inspect interior of filter housing for accumulations or dirt; clean as required.	week
Inspect individual filter elements for damage; repair or replace as required.	week
Check pressure drop across each bank; clean or replace bank as required.	week
Roll Filters	
In addition to the general checks listed above, roll filter units require additional checks as follows:	
Lubricate trunnion bearings.	week
Verify that electric power is to the unit.	week
Verify that the unit is operating; repair or adjust as required.	week
Check pressure drop across filter and check roll filter control settings; adjust as required.	week
Check exposed media for damage; repair, advance media past damage, or replace as required.	week
Check quantity of media remaining on feed roll. Verify that replacement roll is available.	week

Table 7-2. Complex air intake and exhaust systems (continued)

Complex Air Intake & Exhaust Systems	
Action	***Frequency***
Install new roll of media. At installation of new filter media, service roll filter unit as follows and as required:	
Clean roll filter unit to remove accumulations of dirt.	as req'd
Wipe clean and lubricate trunnion bearings.	as req'd
Wipe clean drive motor and lubricate as required.	as req'd
Filter Assembly Bypass Dampers and Air Flow Control Dampers	
Inspect damper assemblies, and report all discrepancies to supervisor. Inspection shall include:	
Verify damper position relative to facility mode of operation.	week
Exercise dampers to verify free operation; repair or adjust as required.	mo
Inspect seals and seal contacting surfaces for full contact; adjust seals and/or repair seals and seal contacting surfaces as required.	mo
Wipe clean damper operator and connecting linkages; apply a light coat of oil.	mo
Clean and inspect bearings; lubricate and adjust bearings as required.	mo
Intake Air Fan	
Inspect fan and report all discrepancies to supervisor. Inspection shall include:	
Check for unusual vibration or noise.	week
Verify drive guards are in place.	week
Visually check drive alignment (and, if belt drive, check for damaged belts).	week
Service fan and fan components. Service shall include:	
Lubricate bearings.	3 mo
Wipe motor clean, clear motor ventilation passages, and lubricate motor as required.	3 mos
Check drive alignment; adjust as required and tighten any loose bolts.	3 mos
If belt drive, inspect pulleys and belts; repair or replace as required; adjust belt tension.	3 mos
If direct-connected or connected through a gear box, inspect shaft couplings, tighten loose bolts, and repair or replace as required. Check lube oil in gearbox; add oil as required.	3 mos
Open fan housing inspection cover, remove accumulations of dirt, and inspect internal components for wear; report all discrepancies to supervisor.	3 mos

Table 7-2. Complex air intake and exhaust systems (continued)

Complex Air Intake & Exhaust Systems	
Action	***Frequency***
Overall System (Air Intake Through Exhaust Port)	
Inspect the air intake and exhaust system; report all discrepancies to supervisor. Work through the system inspecting all devices, assemblies, components, etc., that are part of the intake and exhaust system. Inspection shall include intake and exhaust components that are part of the device being served. Inspection shall include:	
Verify that all components are present and are properly installed; clean, lubricate, tighten, and adjust as required.	mo
Inspect access doors, hatches, and panels, and seal units for proper fit and leaks, tighten, and replace and adjust as required.	mo
Inspect equipment housings and ducts for leaks and/or corrosion; report condition.	mo
Inspect air intake and exhaust manifolds for leaks at joints or visible cracks; report condition.	mo
Inspect expansion joints for visible cracks and/or deformation of expansion joints; report condition.	mo
Inspect ducts for proper support (no sagging or misalignment); report condition.	mo
Inspect duct hanger system for broken and/or deformed hangers; report condition.	mo

Table 7-3. CBR filter bank

CBR Filter Bank	
Action	***Frequency***
NOTE! THE ACTIVATED CARBON SECTIONS OF THE FILTER MUST BE TESTED EVERY TWO YEARS FOR ABSORPTION USING THE FREON TEST. THE TEST IS TO BE PERFORMED BY THE U.S. ARMY EDGEWOOD ARSENAL, QUALITY ASSURANCE OFFICE. ALL GAS FILTERS MUST BE REPLACED EVERY FIVE YEARS WHETHER IN SERVICE OR NOT. ALL PORTIONS OF THE CBR FILTERS MAY BE OBTAINED FROM THE ARMY PROCUREMENT SUPPLY AGENCY (APSA) AT JOLIET, ILLINOIS. THE NECESSITY TO REPLACE THE FILTERS MUST BE ANTICIPATED IN ADVANCE TO ALLOW TIME TO PROCURE THE FILTERS.	
CBR Particulate Filter Element	
Check pressure drop across filter bank; replace particulate filter element as required.	mo
Activated Carbon Filters	
Test absorption of filters using the freon test. Replace filters as indicated by test.	2 yrs
Replace filters.	5 yrs
CBR Filter Assembly	
Inspect filter assembly and report all discrepancies to supervisor. Inspection shall include:	
Visually verify that all filters are properly installed; adjust as required.	mo
Inspect for large debris obstructing the flow of air through the bank; remove obstruction as required.	mo
Inspect interior of filter housing for accumulations or dirt; clean as required.	mo
Inspect individual filter elements for damage; repair or replace as required.	mo
Check pressure drop across each bank; clean or replace bank as required.	mo

Table 7-4. Air intake and exhaust instrumentation and electrical

Air Intake & Exhaust Instrumentation & Electrical	
Action	***Frequency***
Manometers	
Zero manometer; add fluid as required.	week
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 8

COOLING SYSTEMS

8-1. Minimum maintenance activities for cooling systems

The tables located at the end of this chapter indicate items which must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 8-1 provides maintenance information for diesel engine (closed water jacket) cooling systems. Table 8-2 provides maintenance information for cooling towers. Table 8-3 provides maintenance information for cooling system controls and instrumentation.

8-2. General maintenance procedures for cooling systems

This section presents general instructions for maintaining the types of components associated with cooling systems.

a. Coolant preparation and maintenance. When changing or adding coolant to an engine, observe the following guidelines.

(1) Premix the coolant in a clean tank. Never add antifreeze (ethylene glycol) directly into engine cooling system.

(2) Carefully measure additives (coolant conditioner, rust inhibitor, oxygen scavenger, antifreeze, etc.) and water. Excessive levels of some additives when combined with high concentrations of antifreeze may cause mud-like compounds to form which can block the cooling system. Antifreeze concentrations in excess of about 63 percent by volume result in reduced freeze protection. A 50 percent solution of most commercial antifreezes in water will provide freeze protection to about –32°F. (Most undiluted commercial antifreeze freezes at about –10°F.)

(3) Never add coolant to an overheated engine. Allow engine to cool and then add coolant.

(4) When filling an empty engine cooling system, do not add coolant at a rate of more than 10 gallons per minute. Slowly filling a cooling system minimizes the likelihood of air being trapped in the system.

(5) Do not switch from ethylene glycol based antifreeze to methoxypropanol based antifreeze or synthetic antifreeze compounds without verifying suitability with engine manufacturer. Methoxypropanol and synthetic antifreezes are not compatible with seal and gasket materials which are commonly used in cooling systems.

b. Tubular heat exchanger maintenance. Since heat exchangers have no moving parts, heat exchanger maintenance problems generally result from poor coolant maintenance or poor quality cooling water. Another cause of maintenance problems is temperature and pressure cycling as engines are started and stopped.

(1) Heat exchangers are subject to fouling or scaling. A light sludge or scale coating on heat transfer surfaces can greatly reduce the effectiveness of the heat exchanger. This loss of performance may show up as higher than design temperatures or higher than design pressure drops through the heat exchanger unit. Units require periodic cleaning to maintain performance. Sludge or similarly soft deposits on the interior of radiator tubes and both sides of shell and tube heat exchangers may be removed by circulating a hot wash oil or a light distillate through the tubes at a good velocity. Salt deposits may be removed by circulating hot, fresh water through the tubes at a good velocity. If the above methods are not effective, there are many commercial chemical cleaning programs available. Carefully follow the manufacturer's instructions as these programs generally use an acid or caustic wash that must be neutralized to prevent long-term attack on heat transfer surfaces or interference with coolant or cooling water chemical treatment programs.

(2) The air side of air-cooled heat exchangers usually just require cleaning to remove buildups of dirt and grime. Satisfactory cleaning can usually be accomplished by rinsing the outside of tubes with a high pressure stream of fresh water.

(3) When opening or disassembling a heat exchanger for inspection or maintenance:

(a) Do not open inspection ports until all pressure is off the equipment. Do not begin disassembly until the unit has been drained (both sides of a liquid-to-liquid heat exchanger).

(b) Exercise care in handling tube bundle to avoid damaging the tubes. Do not handle tube bundles with hooks or other sharp tools which might damage tubes. A skid, cradle, or other protective device should be used when available.

(c) Thoroughly clean tubes at each cleaning. Leaving any film on the tubes only decreases the time interval to the next cleaning. Avoid using mechanical devices to clean the coolant side (usually the inside) of tubes. Wire brushes and scrappers may be used to assist in cleaning the cooling water (usually the outside) of tubes. Exercise care to minimize damaging the tube surfaces.

(d) Inspect heads for damage and repair as required. On units with tubes rolled into the tube sheet, tighten loose tubes using a suitable roller type tube expander. Only roll loose or leaking tubes as rolling thins the tube walls. Routine rolling of all tubes may result in early failure of the entire tube bundle.

(e) When reassembling the unit, do not tighten bolts on gasketed connections until the gasket has been properly seated. Replacing the gaskets when the unit is reassembled can eliminate having to schedule another shutdown to replace a leaking gasket. Composition gaskets become brittle and dried out and do not provide an effective seal when reused. Metal or metal jacketed gaskets when compressed initially tend to match the gasket contact surfaces and become work-hardened. When reassembled, the joint may not make up the same and a work-hardened gasket will not conform to the mating surfaces. The joint may leak and the mating surfaces may be damaged.

(f) When a new or repaired unit is placed in service, frequently inspect all gasketed joints during the first two days of operation for leaking joints or loose bolts. Tighten and adjust as required.

c. Inspect engine cooling and cooling tower systems. Inspect for:

(1) Obstructions to cooling air paths

(2) Obstructions to the face area of radiators or cooling tower air inlets

(3) Dirty strainers (high pressure drop)

(4) Damage to or deterioration of equipment housings, fan housings, ducts, expansion joints, etc., that would let cooling air leak into the system between the device to be cooled and the fan. This leakage may reduce the air flow through the device being cooled which may reduce the capacity of the system.

(5) Damage to or deterioration of exhaust ducts, flexible connections, and other discharge components that would allow hot moist air to leak into occupied spaces.

(6) Obstructions in dampers, isolation valves, and device operators that would prevent free movement of the device.

(7) Deformed flexible piping connections and expansion joints

(8) Misaligned or sagging pipe and duct sections

(9) Deformed or broken pipe and duct support devices. (Verify that support devices designed to accommodate movement of the duct are free to operate.)

(10) Unusual noise, vibration, or overheating

(11) Loose mechanical or electrical connections

(12) Missing components

(13) Low lube oil levels in equipment with lube oil sumps

(14) Misalignment of drives, worn belts and pulleys, and loose drive belts on belt-driven equipment

(15) Damaged or missing equipment guards

(16) Damaged or missing insulation

(17) Damaged or missing equipment tags

d. Exercise remote operated dampers and valves. Exercise all remote operated dampers and valves.

(1) Verify free operation of dampers and valves.

(2) Inspect any packing glands and tighten as necessary.

(3) Check for leaking seals.

(4) Wipe damper and valve operators clean, apply a light coat of protective oil to exposed operating shafts, and lubricate bearings and pinned connections.

(5) Adjust operator linkages for proper valve positioning, and adjust limit switches for proper position indication.

e. Test alarms. Verify operation of system alarms and alarm system by actuating appropriate system test push buttons. Verify that the audible alarm sounds and that all warning and annunciator lights operate.

f. Rotating equipment clearance adjustment. After long service, the running clearances in some types of rotating equipment (fans, pumps, compressors, etc.) may increase to the point where the device is losing capacity or pressure. Resetting the clearances will normally improve performance. Check clearances during annual inspections and adjust as required. Refer to the manufacturer's Technical Service Manual.

g. Examine internal parts of rotating equipment. Periodically (at least annually), remove casing access covers and inspect components for wear. Replacing a relatively inexpensive part after only moderate wear can eliminate the need to replace more expensive parts at a later date. Refer to manufacturer's technical service manual.

h. Flexible coupling installation and alignment. These instructions cover, in general, the installation of flexible couplings of the pin, gear, or grid types.

(1) Verify that equipment the coupling is serving is completely assembled and adjusted before installing drive coupling.

(2) Install each half cover with seals on its shaft. Consult coupling manufacturer's data to determine proper orientation of long and short shanks of coupling.

(3) For non-taper lock hub units, heat coupling to approximately 300°F by means of a hot oil bath or oven. **Do not apply flame to hub teeth.**

(4) Install coupling hubs on motor and driven shafts. Install shaft keys while hubs are still hot. Face of hub should be flush with end of shaft.

(5) Adjust clearance between the coupling faces. Consult manufacturer's data for proper clearance. (Some coupling units may have required clearance stamped on coupling unit.)

(6) When a sleeve bearing motor is used, locate motor so that when the motor rotor is closest to the driven shaft, the motor shaft will not touch the driven shaft. If the motor shaft has a magnetic center marked, base clearance between coupling faces on magnetic center. Otherwise, determine maximum motor shaft movement and base clearance between coupling faces on one half the motor shaft movement.

(7) With tapered wedge, feeler gauges, or dial indicator, verify that faces of coupling hubs are parallel.

(8) Using a straightedge or dial indicator, verify that motor and driven shafts are parallel. Shim and adjust as required.

(9) After alignment of shafts is obtained, recheck spacing between hub faces and verify that faces are parallel to within 0.001 inch.

(10) When alignment is complete, thoroughly clean both sides of the coupling and inspect all parts for damage. Install the gasket and draw the coupling flanges together keeping gasket holes in line with bolt holes. Insert and tighten bolts, lock washers, and nuts. Lubricate coupling in accordance with manufacturer's data. When aligning shafts, a general rule is to align large motor shafts so the center of the

motor shaft is 0.001 inch lower than the driven shaft for each 1 inch of motor shaft diameter. Turbine shafts or similar large rotating equipment as a general rule are set 0.001 inch lower than the driven shaft for each 1 inch of height from the mounting feet to the center of the shaft. This initial offset provides for thermal expansion of the equipment. After the equipment has been in operation long enough to reach operating temperature, the alignment of the shafts should be checked and adjusted as required.

i. Clean all equipment. Clean all equipment regularly. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

Table 8-1. Diesel engine (closed water jacket) cooling system

Diesel Engine (Closed Water Jacket) Cooling System	
Action	***Frequency***
Coolant	
Check the level of the engine coolant in the expansion tank. Add coolant as required.	day
Test coolant to determine:	
Concentration of oxygen scavengers or corrosion inhibitors. Add water treatment additives to maintain concentrations required by water treatment program. (250 hours of engine operation or monthly, whichever occurs first.)	250 hrs/mo
Freezing point (specific gravity) of coolant in engines requiring antifreeze protection. Drain coolant and add fresh coolant as required to maintain freeze protection.	mo
Drain and clean cooling system and replace engine coolant with new coolant. (At 6,000 hours of engine operation or yearly, whichever occurs first.)	6K hrs/yr
Overall Engine Cooling System	
Clean and inspect all of the components and piping associated with engine cooling system and report all discrepancies to supervisor. Inspect for:	
Leaking piping or equipment (gaskets, seals, packing, etc.)	mo
Corrosion.	mo
Sagging or misaligned piping.	mo
Damaged flexible connectors or expansion joints.	mo
Loose equipment, piping, or electrical connections. (Correct during inspection if possible).	mo
Incorrect level, temperature, or pressure gauge operation.	mo
Hot or noisy bearings, and equipment with unusual vibration or noise.	mo
Exercise all cooling system valves and perform routine maintenance as follows:	
Grease stems on OS&Y valves.	mo
Verify correct position and operation.	mo
Check for leaking seals.	mo
Wipe valve operator rods clean and apply a light coat of protective oil.	mo
Adjust operator linkages and limit switches.	mo
Keep Warm System Immersion Heater	
Remove heating element and inspect for scaling, corrosion, or excessive oxidation. Report discrepancies to supervisor.	yr

Table 8-1. Diesel engine (closed water jacket) cooling system (continued)

Diesel Engine (Closed Water Jacket) Cooling System	
Action	***Frequency***
Keep Warm Circulating Pump	
Lubricate bearings.	3 mos
Engine Driven Circulating Pump	
Inspect, repair, and maintain, in accordance with engine maintenance schedule.	as req'd
Air Separators	
Blow down separator on initial engine startup or after major cooling system maintenance. (Daily until dirt clears from system.)	day
Blow down separator during routine engine operation. (Weekly or as required by coolant treatment program.)	week
Inspect and clean strainer element.	mo
Strainers	
Remove and inspect strainers on nonoperating engines and clean as required.	mo
Coolant Heat Exchangers	
After initial engine start or after engine has been out of service for major maintenance, inspect units for leaks, and adjust and tighten gasketed joints as required. (Each 8-hour shift for 2 days following startup)	8 hrs
During operation, monitor and record engine coolant inlet and outlet temperatures (and for liquid cooled units, cooling water inlet and outlet temperatures) as a means of monitoring the condition of heat transfer surfaces.	week
Inspect, repair, and clean heat transfer surfaces of liquid-to-liquid heat exchangers (tube side and shell side).	yr
Inspect, repair, and clean heat transfer surfaces of air-cooled heat exchangers:	
Engine coolant side.	yr
Inspect unit and remove obstructions blocking air path.	day
Wash radiators on non-operating engines to remove dirt	3 mos
Radiator Propeller Fans	
Clean and inspect units and perform routine maintenance. Report all discrepancies to supervisor.	
Check and tighten set screws and bolts in fan hub and fan bearings.	week
Visually check drive alignment and clearances between fan blades and housing. Adjust as required.	week
On belt driven units, inspect belts and pulleys.	week

Table 8-1. Diesel engine (closed water jacket) cooling system (continued)

Diesel Engine (Closed Water Jacket) Cooling System	
Action	***Frequency***
When fan is operating, check for hot shafts and bearings, and any unusual noise or vibration.	week
On belt driven units, measure belt tension and adjust as required.	mo
Lubricate all bearings (except motor bearings).	
Sleeve bearings.	mo
Ball bearings.	3 mos
Roller bearings.	mo
Temperature Control Valves	
Remove from system and inspect internal components. Verify operation. Repair or replace parts as required. Perform work in accordance with manufacturer's recommendations.	yr
Alarms and Annunciators	
Verify operation of system alarms and annunciators using control system test and reset (or acknowledge) function each shift.	shift

Table 8-2. Cooling tower

Cooling Tower	
Action	***Frequency***
Spray Water System and Equipment	
Inspect and perform routine maintenance, and report all discrepancies to supervisor.	
Check water chemistry.	week
Check water level in pan and adjust makeup water valve as required.	mo
Check operation of blowdown valve. In general blowdown rate should be equal to rate of evaporation.	mo
Inspect and clean all strainer elements.	mo
Inspect spray nozzles and clean as required.	mo
Inspect spray pump(s) for leaking seals.	mo
Inspect cooling coils for scaling or corrosion. Brush exterior surfaces of coil with stiff bristle brush and flush with fresh water.	mo
Drain pan. Brush interior surfaces with stiff bristle brush and flush with fresh water.	mo
Inspect entire unit for leaks, corrosion, and cleanliness.	mo
Inspect housing and pan for corrosion or damaged coatings and repair coatings as required.	yr
All Rotating Equipment (Fans and Pumps)	
Inspect equipment and perform routine maintenance, and report all discrepancies to supervisor.	
Check for hot bearings.	week
Check for unusual noise or vibration.	week
Check tightness of fasteners (nuts, machine screws, set screws, shaft collars, etc.) and tighten as required.	mo
Visually inspect drive alignment.	mo
Lubricate bearings:	
Sleeve bearings.	mo
Ball bearings.	3 mos
Roller bearings.	mo
For units with belt drives inspect belts and pulleys.	mo
Measure belt tension and adjust as required.	mo

Table 8-2. Cooling tower (continued)

Cooling Tower	
Action	***Frequency***
Pumps	
Check packing and adjust as required.	mo
Inspect internal components, replace as required, and adjust in accordance with manufacturer's recommendations.	yr
Fans	
Inspect fan blades (or fan wheel) for buildup of dirt or scale, use soft brush or clean rages to loosen or remove dirt, and flush surfaces with clean water.	mo
CAUTION! SOME FANS MAY HAVE INTERNAL COMPONENTS PROTECTED WITH CORROSION RESISTANT COATINGS WHICH CAN BE DAMAGED EASILY. DO NOT USE CLEANING TOOLS OR MATERIALS THAT WILL DAMAGE COATINGS.	
Inspect internal components and repair or replace as required. This includes repairing defects in protective coatings. If work performed on fan wheel, check balance and rebalance as required.	yr
Dampers	
Inspect damper assemblies, and report all discrepancies to supervisor. Inspection shall include:	
Verify damper position relative to facility mode of operation. Adjust position indication switches as required.	week
Exercise dampers to verify free operation; repair or adjust as required.	mo
Inspect seals and contacting surfaces for full contact; adjust and/or repair seals and contacting surfaces as required.	mo
Wipe clean damper operator and linkages; apply a light coat of oil.	mo
Clean and inspect bearings; lubricate and adjust bearings as required.	mo
Remote Operated Valves	
Verify valve position. Adjust position indication switches as required.	week
Clean rods on valve operator and apply a light coat of protective oil.	mo
Inspect seals.	mo
Inspect and tighten packing.	mo
All Valves	
Exercise all valves and perform routine maintenance and report all discrepancies to supervisor.	

Table 8-2. Cooling tower (continued)

Cooling Tower	
Action	***Frequency***
Grease stems on OS&Y valves.	mo
Inspect packing gland and tighten as necessary.	mo
Verify correct position and operation.	mo
Check for leaking seals.	mo

Table 8-3. Cooling system instrumentation and electrical

Cooling System Instrumentation & Electrical	
Action	***Frequency***
Transmitters and Controllers	
Calibrate and adjust in accordance with the manufacturer's recommendations.	yr
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 9

BOILERS

9-1. Minimum maintenance activities for boilers

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 9-1 provides maintenance information for packaged heating boilers. Table 9-2 provides maintenance information for boiler system instrumentation and electrical systems.

9-2. General maintenance for boilers

This section presents general instructions for maintaining the types of components associated with boilers.

a. Exercise valves. Exercise all valves in the heating boiler system.

(1) Inspect packing gland and tighten if necessary.

(2) Check for correct positioning and operation.

(3) Check for leaking seals.

(4) Adjust operator linkages and limit switches on control valves.

b. Test alarms. Verify that the horns sound and all annunciator lights illuminate by pressing the appropriate test push buttons. Press the ACKNOWLEDGE and RESET push buttons when proper operation has been confirmed.

c. Lubricate rotating equipment. Grease all zerks at the manufacturer-recommended service interval. Grease gently with a handgun to avoid damage to grease seals. Do not overgrease.

(1) Ball or roller bearings tend to heat up when overgreased and will cool down to normal running temperatures when the excess grease either oozes out or is wiped off. The normal operating temperature of a bearing may be well above 140°F which is "hot" to touch. Temperatures should be checked with a thermometer and any temperature readings over 180°F should be questioned. If a drop of water placed on a bearing sizzles, the bearing is in distress and should be changed before it seizes and ruins the shaft. For sleeve bearing assemblies with oil reservoirs, service reservoirs at manufacturer-recommended interval with recommended viscosity lubricating oil. Do not overfill reservoir as overheating may result. When new sleeve bearing units are placed in service, drain and flush the oil reservoir after about two weeks of operation and refill the reservoir with new lubricating oil of the proper viscosity.

(2) During equipment overhauls, bearing assemblies should be thoroughly cleaned, inspected, and adjusted in accordance with the manufacturer's recommendations. All old grease should be removed from bearings and the bearings repacked with grease a minimum of every two years. Monitor the operation of

all recently installed bearings. Check for overheating (alignment, lubrication), vibration (alignment), loose collars, fasteners, etc. Early problem detection can avoid early failure and costly replacement.

d. Belt drives. When belt replacement is required replace multiple belts as a set. Loosen drive motor mounting, and slide motor toward driven shaft so that belts may be installed by laying belts onto pulleys. Do not lever belts onto pulleys. Check belt tension several times during first 48 hours that new belts are in operation, and adjust belt tension as required.

(1) When belt tension adjustment is required, consult the belt manufacturer's literature for the proper tension force (and belt deflection to achieve that force). Deflect each belt at the midpoint between the pulleys to the deflection recommended, and read the belt tension. Adjust the tension as required. Many belts have an initial run-in period tension (usually about 48 hours) and then a broken-in tension. Generally, if the tension reading differs more than 2 pounds from the recommended reading, the belt tension should be adjusted. If a belt tension measuring device is not available, belt tension may be checked by observing the deflection when pressing down on each belt at about the midpoint between the pulleys. If the tension is correct, the belt deflection will be about one belt thickness for each 4 feet of center-to-center distance between the pulleys. Caution should be used in using this method because there are many different belt designs available for the same service and each belt design may have different tension and deflection characteristics. To tension the belts, loosen the motor hold-down bolts. Move the motor away from the driven shaft to increase the tension and toward the driven shaft to decrease the tension. (If the motor is on a slide base, it will not be necessary to loosen the motor hold-down bolts. Adjustment is accomplished using the slide base positioning screw.) Tighten the motor hold-down bolts. Run the equipment for a short period of time, and then check the belt tension.

(2) When drive alignment is required, lay a straightedge across both the driver and driven pulleys. The straightedge should contact each pulley in two places. If the pulleys are not aligned, verify that the drive shaft and driven shaft are parallel. If the shafts are not parallel, adjust the motor so the shafts are parallel. When the shafts are parallel, adjust the positions of the pulleys on the shafts to achieve alignment. Verify that the driven pulley is in the correct position on the driven shaft and that the pulley is firmly locked in place. Loosen the pulley on the motor shaft, and move the pulley into alignment with the driven pulley. Tighten the pulley on the shaft, install and tension the drive belts, and run the equipment for a short period of time. Check drive alignment and adjust as required.

e. Packing adjustment. Occasional packing adjustment may be required to keep leakage to a slight weep; if impossible to reduce leakage by gentle tightening, replace packing. A slight weeping through the packing gland is required so that the process fluid provides lubrication for the packing material. Maintain a supply of the recommended type and size of packing required for the equipment. Do not substitute one type of packing with another without verifying the packing types are compatible. Do not use oversized packing. If diameter of oversized packing is reduced by hammering, early failure of packing may result. A too tight packing joint may interfere with equipment operation, can damage equipment, and, again, may result in early failure of the packing. The procedure to follow when replacing packing is as follows.

(1) Remove all old packing.

(2) Inspect shaft for wear and replace as required.

(3) Use proper size packing and cut packing into rings using the shaft as a guide. When cutting to length, hold packing tightly around shaft but do not stretch packing. Cut with a butt joint. **Do not wind packing around shaft.**

(4) Thoroughly clean shaft and housing.

(5) Install one ring at a time. Oil or grease lubrication, if permitted, will assist when packing the ring into the box. Offset joints of each succeeding ring by at least 90 degrees from the previous ring.

(6) If shaft is equipped with a lantern ring, be sure that lantern ring is slightly behind lubrication hole in stuffing box; otherwise, the lantern ring will move forward when the gland is taken up and the packing behind the ring may plug the lubrication hole.

(7) Tighten the gland bolts all the way to seat the packing. Then loosen the nuts until the nuts are finger tight. In most applications, newly installed packing should be allowed to leak freely on startup. After startup, tighten packing gland until only 2 to 3 drops a second are leaking. **Do not try to stop leakage entirely.** The leakage lubricates the packing and prevents early failure of the packing and shaft.

f. Mechanical seals. There are many different mechanical seal designs. As a result, there is no standard procedure for maintaining and installing mechanical seals. Mechanical seal installations commonly fail because the seal was not placed in the correct position. Seal faces may wear rapidly resulting in early seal failure if the spring has too much initial compression. This results in too much force between the faces of the seal which does not allow proper lubrication of the surfaces. Alternately, if the spring has too little initial compression, the seal faces separate at normal operating pressures and leak. It is important that manufacturer's information for the seals used be obtained and closely followed. In general, there are four critical requirements in any seal installation as follows.

(1) Determine that the equipment is ready to have the seal installed, shaft and seal housing have been inspected and repaired as required, and the components have been thoroughly cleaned.

(2) Place the seal in the correct position for the right operating length (consult manufacturer's data).

(3) Prevent damage to seal rings.

(4) Prevent damage to seal faces.

g. Clean all equipment. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

h. Safety relief valve test (steam boilers). As precautionary measures, all personnel concerned with conducting a pop or capacity test should be briefed on the location of all shutdown controls in the event of an emergency, and there should be at least two people present. Care should be taken to protect those present from escaping steam.

(1) Every 30 days that the boiler is in operation or after any period of inactivity, a try lever test should be performed as follows. With the boiler under a minimum of 5 psi pressure, lift the try lever on the safety valve to the wide open position and allow steam to be discharged for five seconds to 10 seconds. Release the try lever, and allow the spring to snap the disk to the closed position. If the valve simmers, operate the try lever two or three times to allow the disk to seat properly. If the valve continues to simmer, it must be replaced or repaired by an authorized representative of the manufacturer. Inspect the valve for evidence of scale or encrustation within the body. Do not disassemble valve or attempt to adjust the spring setting. It is advisable to have a chain attached to the try lever of the valve to facilitate this test and allow it to be conducted in a safe manner from the floor. The date of this test should be entered into the boiler logbook.

(2) A pop test of a safety valve is conducted to determine that the valve will open under boiler pressure within the allowable tolerances. It should be conducted annually, preferably at the beginning of the heating season if the boiler is used only for space heating purposes. Hydrostatic testing (using water) is not to be considered an acceptable test to check safety valve opening pressure. A recommended procedure is as follows.

(a) Establish necessary trial conditions at the particular location. Where necessary, provide adequately supported temporary piping from the valve discharge to a safe location outside the boiler room. In some installations, temporary ventilation may dispose of the steam vapor satisfactorily. Review preparation for test with personnel involved. All such tests should have at least two people present.

(b) Install temporary calibrated test pressure gauge to check accuracy of boiler gauge.

(c) Isolate the boiler by shutting the stop valves in the steam supply and condensate return piping.

(d) Temporarily place jumper leads across the appropriate terminals on the operating control to demonstrate the ability of the high-limit pressure control to function properly. After this has been checked, place another set of jumper leads across the high-limit pressure control terminals to permit continuous operation of the burner.

(e) The safety valve should pop open at an acceptable pressure, i.e., 15 psi ±2 psi. A simmering action will ordinarily be noticed shortly before the valve pops to the open position.

(f) If the valve does not open in the 13 psi to 17 psi range, it should be replaced. It is not necessarily a dangerous situation if the valve opens below 13 psi, but it could indicate a weakening of the spring, improper setting of the spring, etc. If the valve does not open at 17 psi, shut off the burner and dissipate the steam to the system by slowly opening the supply valve.

(g) If the valve pops open at an acceptable pressure, immediately remove the jumper leads from the high-limit pressure control. The burner main flame should cut off as soon as the jumper leads are removed.

(h) The safety valve will stay open until the pressure drops sufficiently in the boiler to allow it to close, usually 2 psi to 4 psi below the opening pressure. This pressure drop (blowdown) is usually indicated on the safety valve nameplate.

(i) Relieve the higher pressure steam to the rest of the system by slowly opening the steam supply valve. After the boiler and supply piping pressures have become equalized, open the return valve.

(j) Remove the jumper leads from the operating control and check to make certain that it functions properly. This is best done by allowing it to cycle the burner on and off at least once.

(k) Enter the necessary test data into the boiler logbook.

i. Safety relief valve test (water boilers). At try lever, test and pop test should be performed for water boilers as described below.

(1) Every 30 days that the boiler is in operation or after any prolonged period of inactivity, a try lever test should be performed as follows.

(a) Prior to the test, check the safety relief discharge piping to make sure it is installed and supported so this test does not transmit any stress or strain to the body of the safety relief valve.

(b) Check and log the operating pressure and temperature of the system.

(c) Shut off circulating pump and fuel burning equipment.

(d) Isolate the boiler from the system, leaving the expansion tank valve and the automatic fill valve open.

(e) With the boiler at operating pressure, lift the try lever to the full open position and hold it open for at least five seconds or until clean water is discharged.

(f) Release the lever and allow the spring to snap to the closed position. If the valve leaks, operate the try lever two or three times to clear the seat of any foreign matter that is preventing proper seating. As safety relief valves are normally piped to the floor or near a floor drain, it may take some time to determine if the valve has shut completely.

(g) If the safety relief valve continues to leak, it must be replaced before the boiler is returned to operation.

(h) After it has been determined that the safety relief has shut completely, add water to the boiler until the pressure rises to the initial pressure which was logged at the start of the test.

(i) Open the valves to the system.

(j) Start the circulating pump.

(k) Start the fuel burning system.

(l) Observe the pressure and temperature until the system returns to operating conditions and operating control has cycled the burner on and off at least once.

(m) Check again to ensure that the safety relief valve is not leaking.

(2) A pop test (pressure relief valve) should be performed annually, preferably at the beginning of the heating season, if the boiler is shut off during the summer months. The following procedure should be reviewed by the person in charge of the test with at least one other person, and trial conditions should be determined.

(a) Isolate the boiler from the rest of the heating system by closing the supply and return valves. On large water content boilers, the expansion tank may also be isolated to speed up pressure rise.

(b) Check the safety relief valve discharge piping to make sure it is installed and supported so that this test does not transmit any detrimental stress to the body of the safety relief valve.

(c) Temporarily install a calibrated pressure gauge and thermometer to check the accuracy of the boiler pressure gauge and thermometer or remove gauge and thermometer and check calibration and reinstall prior to test.

(d) Perform a try lever test prior to the beginning of the pop test.

(e) Check and log the system operating pressure and temperature.

(f) Shut off circulating pump and fuel burning equipment.

(g) If an automatic water feeder is provided, close the boiler water inlet valve.

(h) Turn on the fuel burning equipment.

(i) Place jumper leads across the appropriate terminals of the operating temperature control and check the operation of the high-temperature cutout.

(j) If the high-temperature cutout functions properly, place jumper leads across the appropriate terminals of the high-temperature cutout to permit continuous operation of the burner.

(k) Make sure that all personnel are clear of the safety relief valve discharge**. On boilers having a small water storage capacity, very little heat will be required to raise the boiler pressure to the popping pressure of the safety relief valve.**

(l) The safety relief valve should open within an acceptable range above or below the set point. This range is ±2 psi for valves set to open at 70 psi or less and ±3 percent of set pressure for valves set to open at more than 70 psi.

(m) If the safety relief valve does not open at the set pressure plus the allowable tolerance, shut off the fuel burning equipment and do not operate the boiler until the safety relief valve has been replaced.

(n) Observe the rising pressure and temperature of the boiler, and log the pressure at which the safety relief valve opens. As soon as the safety relief valve opens, turn off fuel burning equipment by removing jumper leads and record safety relief valve closing pressure.

(o) If the safety relief valve opens at a pressure below the allowable tolerance, this is not necessarily a dangerous condition, but it can indicate a deteriorating condition or improper spring setting. The valve should be replaced.

(p) When the safety relief valve opens, it will discharge a mixture of water and vapor. The valve will remain open until a closing pressure is reached. This pressure may be 20 percent to 50 percent below the set pressure of the valve. There are no blowdown tolerance requirements for safety relief valves.

(q) After the safety relief valve has closed, add water to the boiler, if necessary, until the boiler pressure rises to the initial system operating pressure that was logged at the start of the test.

(r) Open the supply and return valves to the system and expansion tank valve, if closed, and open the boiler water inlet valve if an automatic water feeder is provided.

(s) Start the circulating pump.

(t) Start the fuel burning equipment.

(u) Observe the pressure and temperature until the system returns to operating conditions and the operating control has cycled the burner on and off at least once.

(v) Check again to ensure that the safety relief valve is not leaking.

Table 9-1. Packaged heating boiler

Packaged Heating Boiler	
Action	***Frequency***
System	
Check and record pressure and temperature readings.	shift
Perform walk-around inspection of boiler system. Make routine adjustments and repairs when discovered if possible; initiate report orders for items that cannot be corrected at inspection. Tag deficient devices to alert others that item needs repair.	day
Inspection should observe all operating equipment and look, listen, and feel for unusual conditions. Inspection should include:	
Feedwater system (pumps operating, valves open, chemical treatment operating).	day
Safety valves leaking or simmering.	day
Water level controls operating.	day
Filters and strainers are not plugged.	day
Devices such as steam traps, drain cooling valves, etc., are operating properly.	day
For fuel oil fired systems, level of fuel oil is adequate and fuel feed equipment is operating properly.	day
Safety and Ignition Devices	
Inspect, operate, and report on all safety and ignition devices. Report all deficiencies found. Where possible, make required adjustments or repairs to device during inspection. Otherwise, tag device to alert others to deficiency and initiate repair order. Devices to be inspected and tested include:	
All systems:	
Pressure relief valves.	mo
All low water shutoff devices.	mo
All flame detecting devices and operation of flame supervisory control system.	mo
Ignition transformer.	mo
Modulating motor transformer.	mo
Combustion air proving switch.	mo
Combustion air control damper.	mo
Steam Boilers:	
Operating limit pressure control.	mo
High limit pressure control.	mo

Table 9-1. Packaged heating boiler (continued)

Packaged Heating Boiler	
Action	***Frequency***
Modulating pressure control.	mo
Hot Water Boilers:	
Operating limit temperature control.	mo
High limit temperature control.	mo
Modulating temperature control.	mo
Gas Fired Boilers:	
Gas pilot solenoid valve.	mo
Gas pilot solenoid vent valve.	mo
Gas pilot pressure regulating valve.	mo
Main gas pressure regulating valve (if required).	mo
Main gas modulating cam.	mo
Main gas solenoid valve.	mo
High gas pressure shutdown switches.	mo
Main gas solenoid vent valve.	mo
Low gas pressure shutdown switches.	mo
All Oil Fired Boilers:	
Oil drawer switch.	mo
Atomizing air proving switch.	mo
Low oil pressure shutdown switches.	mo
Main oil solenoid valve.	mo
Fuel oil controller.	mo
Heavy Oil Fired Boilers:	
Startup electric oil heater thermostat.	mo
Main oil heater thermostat.	mo
Low oil temperature switch.	mo
High oil temperature switch.	mo

Table 9-1. Packaged heating boiler (continued)

Packaged Heating Boiler	
Action	***Frequency***
Fan, Pump and Other Rotating Equipment	
Observe operation and check for unusual noises, vibration, and overheating. Investigate and report all unusual conditions. When possible, make adjustments and repairs when condition is observed. When immediate correction cannot be accomplished, initiate work order and tag equipment to alert others of condition.	day
Lubricate equipment:	
Sleeve bearings.	mo
Ball bearings.	3 mos
Roller bearings.	mo
For belt driven equipment, check condition of drive belts and pulleys, and belt tension. Replace components, and adjust belt tension as required.	mo
Thoroughly inspect equipment (partial disassembly may be required) and service equipment in accordance with manufacturer's recommendations.	yr
Strainers and Filters	
Check pressure drop across strainer and filter elements. Clean or replace element if pressure drop exceeds design value.	week
Clean all filters and strainers.	3 mos
Steam Traps	
Check temperature on both sides of steam trap. If above the boiling point several feet past the steam trap, it has failed in the open position.	3 mos
Burner Assembly	
Visually check flame during operation. Investigate unusual conditions and make adjustments to burner, combustion air, and fuel train to achieve optimum air-fuel ratios. Perform value gas analysis as required.	week
Perform flue gas analysis and adjust burner as required.	3 mos
Clean and inspect burner assembly and combustion control equipment. Adjust or repair as required.	6 mos
Rebuild burner assembly in accordance with manufacturer's recommendations.	yr
Fireside	
Inspect combustion chamber and flue gas side of boiler equipment. Report all deficiencies. Make all possible adjustments and repairs during inspection. For items that cannot be corrected during the inspection, initiate work orders to correct the conditions. Inspection and routine maintenance to be performed during the inspection shall include:	

Table 9-1. Packaged heating boiler (continued)

Packaged Heating Boiler	
Action	***Frequency***
Vacuum, brush, or scrape all soot and obstructions from combustion chamber walls, fire tube walls, and exhaust gas flues.	6 mos
Inspect refractory liner for deterioration.	6 mos
Inspect metal surfaces for corrosion, cracking, or other deterioration.	6 mos
Waterside	
For steam boilers with minimal makeup water requirements (no condensate or makeup water treatment program – usually small boilers operating at 15 psig or less), drain and flush boiler, and refill boiler with chemically treated, softened, or deionized water.	6 mos
For closed loop hot water boilers, drain and flush boiler, and refill boiler with chemically treated, softened, or deionized water.	yr
For steam boilers with water treatment systems:	
Verify operation of makeup water and feedwater treatment equipment and systems. Includes checking levels in chemical supply tanks and preparing additional chemical treatment solutions as required.	day
Test water and adjust chemical treatment as required.	week

Table 9-2. Boiler system instrumentation and electrical

Boiler System Instrumentation & Electrical	
Action	***Frequency***
Level Gauges	
Check for accuracy. Recalibrate as required following equipment manufacturer's instructions.	yr
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controller temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
pH Probes	
Remove probe from line and rinse with fresh water. Calibrate pH unit in accordance with manufacturer's recommendations.	week
Conductivity Probes	
Remove probe from lien and rinse with fresh water. Calibrate conductivity unit in accordance with manufacturer's recommendations.	week
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 10

INCINERATORS

10-1. Minimum maintenance activities for incinerators

The tables located at the end of this chapter indicate items which must be performed to maintain systems and equipment as a minimum level of operational readiness. The listed action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 10-1 provides maintenance information for incinerators. Table 10-2 provides maintenance information for incineration system instrumentation and electrical systems.

10-2. General maintenance procedures for incinerators

See the equipment manufacturer's data for specific instructions regarding maintenance of components associated with incinerators.

Table 10-1. Incinerator

Incinerator	
Action	***Frequency***
Combustion Unit	
Check underfire air covers and supply tubes for clogging (excessively oxidized air covers or those with holes burned in them should be replaced).	3 mos
Remove inspection plates and inspect the underfire air manifolds.	3 mos
Check the door gasket for wear or fraying.	6 mos
Check door hinges and lubricate as required.	6 mos
Auxiliary Burner (Gas)	
Check spark plug and flame rod for fouling or cracked ceramic.	3 mos
Check gas pilot during operation.	3 mos
Check gas and air cocks, main gas regulator, and gas solenoid valve.	3 mos
Check gas burner operation.	3 mos
Induced Draft Fan	
Clean and wipe down fan assemblies, including motors, drives, and mountings. Inspect the fan assemblies for correct operation. Check for undue noise or vibration that could indicate possible malfunctions. Correct and report deficiencies.	6 mos
Remove inspection caps on the top of the bearing and be sure oil rings turn and carry oil.	6 mos
Change the oil in accordance with the manufacturer's recommendation.	6 mos
Check and tighten bolts aligning fan wheel on the shaft.	6 mos
Check and tighten pedestal holding bolts.	6 mos
Flue and Stack	
Inspect for a residue buildup. Clean as required.	3 mos
Inspect and clean spark screen.	3 mos
Inspect for loose joints or damaged refractory. Report any discrepancies to supervisor.	6 mos

Table 10-2. Incineration system instrumentation and electrical

Incineration System Instrumentation & Electrical	
Action	***Frequency***
Control Switches	
Check low limit and high gas pressure switches and gas safety shutoff.	3 mos
Check tubing to air pressure switches for blocking.	yr
Thermocouples	
Check thermocouple shields for cracks or holes.	6 mos
Indicators	
Check the operation of all indicating meters and lights while the unit is in operation. Replace defective meters and lights as required.	6 mos
Control Cabinet	
Ensure that the control cabinet doors are securely closed at the end of each frequency to prevent tampering and migration of dust and moisture into the cabinet.	6 mos
Transmitters and Controllers	
Calibrate and adjust in accordance with the manufacturer's recommendations.	mo
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 11

CHILLED WATER SYSTEMS

11-1. Minimum maintenance activities for chilled water systems

The tables located at the end of this chapter indicate items which must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 11-1 provides maintenance information for chilled water system centrifugal chillers. Table 11-2 provides maintenance information for chilled water system pumps. Table 11-3 provides maintenance information for chilled water system piping. Table 11-4 provides maintenance information for refrigerant compressors used in thermal storage systems. Table 11-5 provides maintenance information for refrigerant piping and accessories of thermal storage systems. Table 11-6 provides maintenance information for chilled water system instrumentation and electrical systems.

11-2. General maintenance procedures for chilled water systems

This section presents general instructions for maintaining various components for a typical chilled water system.

a. Tubular heat exchanger maintenance. Since heat exchangers have no moving parts, heat exchanger maintenance problems generally result from poor coolant maintenance or poor quality cooling water. Another cause of maintenance problems is temperature and pressure cycling as chillers/compressors are started and stopped.

(1) Heat exchangers are subject to fouling or scaling. A light sludge or scale coating on heat transfer surfaces can greatly reduce the effectiveness of the heat exchanger. This loss of performance may show up as higher than design temperatures or higher than design pressure drops through the heat exchanger unit. Units require periodic cleaning to maintain performance. Sludge or similarly soft deposits on the interior of radiator tubes and both sides of shell and tube heat exchangers may be removed by circulating a hot wash oil or a light distillate through the tubes at a good velocity. Salt deposits may be removed by circulating hot, fresh water through the tubes at a good velocity. If the above methods are not effective, there are many commercial chemical cleaning programs available. Carefully follow the manufacturer's instructions as these programs generally use an acid or caustic wash that must be neutralized to prevent long-term attack on heat transfer surfaces or interference with chilled water chemical treatment programs.

(2) The air side of air-cooled heat exchangers usually requires cleaning to remove buildups of dirt and grime. Satisfactory cleaning can usually be accomplished by rinsing the outside of tubes with a high-pressure stream of fresh water.

(3) When opening or disassembling a heat exchanger for inspection or maintenance:

(a) Do not open inspection ports until all pressure is off the equipment. Do not begin disassembly until the unit has been drained (both sides of a liquid-to-liquid heat exchanger).

(b) Exercise care in handling tube bundle to avoid damaging the tubes. Do not handle tube bundles with hooks or other sharp tools which might damage tubes. A skid, cradle, or other protective device should be used when available.

(c) Thoroughly clean tubes at each cleaning. Leaving any film on the tubes only decreases the time interval to the next cleaning. Avoid using mechanical devices to clean the coolant side (usually the inside) of tubes. Wire brushes and scrapers may be used to assist in cleaning the cooling water side (usually the outside) of tubes. Exercise care to minimize damaging the tube surfaces.

(d) Inspect heads for damage and repair as required. On units with tubes rolled into the tube sheet, tighten loose tubes using a suitable roller type tube expander. Only roll loose or leaking tubes, as rolling thins the tube walls. Routine rolling of all tubes may result in early failure of the entire tube bundle.

(e) When reassembling the unit, do not tighten bolts on gasketed connections until the gasket has been properly seated. Replacing the gaskets when the unit is reassembled can eliminate having to schedule another shutdown to replace a leaking gasket. Composition gaskets become brittle and dried out and do not provide an effective seal when reused. Metal or metal-jacketed gaskets when compressed initially tend to match the gasket contact surfaces and become work-hardened. When reassembled, the joint may not make up the same and a work-hardened gasket will not conform to the mating surfaces. The joint may leak and the mating surfaces may be damaged.

(f) When a new or repaired unit is placed in service, frequently inspect all gasketed joints during the first two days of operation for leaking joints or loose bolts. Tighten and adjust as required.

b. Test alarms. Verify operation of system alarms and alarm system by actuating appropriate system test push buttons. Verify that the audible alarm sounds and that all warning and annunciator lights operate.

c. Rotating equipment clearance adjustment. After a long service, the running clearances in some types of rotating equipment (fans, pumps, compressors, etc.) may increase to the point where the device is losing capacity or pressure. Resetting the clearances will normally improve performance. Check clearances during annual inspections, and adjust as required. Refer to the manufacturer's technical service manual.

d. Examine internal parts of rotating equipment. Periodically (at least annually), remove casing access covers and inspect components for wear. Replacing a relatively inexpensive part after only moderate wear can eliminate the need to replace more expensive parts at a later date. Refer to the manufacturer's technical service manual.

e. Flexible coupling installation and alignment. The following instructions cover, in general, the installation of flexible couplings of the pin, gear, or grid type.

(1) Verify that equipment the coupling is serving is completely assembled and adjusted before installing drive coupling.

(2) Install each half cover with seals on its shaft. Consult coupling manufacturer's data to determine proper orientation of long and short shanks of coupling.

(3) For non-taper lock hub units, heat coupling to approximately 300°F by means of a hot oil bath or oven. **Do not apply flame to hub teeth.**

(4) Install coupling hubs on motor and driven shafts. Install shaft keys while hubs are still hot. Face of hub should be flush with end of shaft.

(5) Adjust clearance between the coupling faces. Consult manufacturer's data for proper clearance. (Some coupling units may have the required clearance stamped on the coupling unit.)

(6) When a sleeve bearing motor is used, locate the motor so that when the motor rotor is closest to the driven shaft, the motor shaft will not touch the driven shaft. If the motor shaft has a magnetic center marked, base clearance between coupling faces on magnetic center. Otherwise, determine maximum motor shaft movement and base clearance between coupling faces on one half of the motor shaft movement.

(7) With tapered wedge, feeler gauges, or dial indicator, verify that faces of coupling hubs are parallel.

(8) Using a straightedge or dial indicator, verify that motor and driven shafts are parallel. Shim and adjust as required.

(9) After alignment of shafts is obtained, recheck spacing between hub faces and verify that faces are parallel to within 0.001 inch.

(10) When alignment is complete, thoroughly clean both sides of the coupling and inspect all parts for damage. Install the gasket and draw the coupling flanges together keeping gasket holes in line with bolt holes. Insert and tighten bolts, lock washers, and nuts. Lubricate coupling in accordance with the manufacturer's data. When aligning shafts, a general rule is to align large motor shafts so the center of the motor shaft is 0.001 inch lower than the driven shaft for every 1 inch of motor shaft diameter. Turbine shafts or similar large rotating equipment, as a general rule, are set 0.001 inch lower than the driven shaft for every 1 inch of height from the mounting feet to the center of the shaft. This initial offset provides for thermal expansion of the equipment. After the equipment has been in operation long enough to reach the operating temperature, the alignment of the shafts should be checked and adjusted as required.

f. Clean all equipment. Clean all equipment regularly. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

Table 11-1. Chilled water system (centrifugal chillers)

Chilled Water System (Centrifugal Chillers)	
Action	***Frequency***
Centrifugal Chiller (Operating)	
Check control center gauges and lights, excess purge light, and remote start operations.	shift
Record the bearing oil pressure and check oil level in the oil sump. Drain or add oil as required.	shift
Check the inlet and outlet water pressures and temperatures for variations with normal values.	shift
Record liquid refrigerant temperature leaving the condenser.	shift
Record the compressor discharge temperature (should not exceed 220 F).	shift
Check for signs of dirty or fouled condenser tubing (the temperature difference between the water outlet and refrigerant outlet should not be larger than 4 F).	shift
Record the compressor motor voltage and amperage at the starter.	shift
Centrifugal Chiller (Off-Line)	
Clean and wipe down the condenser, compressor, motor control panel, and associated pumps and piping. Inspect the unit and motor base. Tighten all loose bolts, fasteners, and anchors.	week
Check for oil, refrigerant, and/or water leaks. Verify proper water treatment.	week
Check the refrigerant charge.	week
Check the drive coupling on the motor/compressor unit. Realign as required.	mo
Inspect the electrical wiring, connections, control switches, switch contacts, starter contacts, and fuses. Repair or replace as required.	mo
Change the purge filter drive.	3 mos
Inspect and clean the purge foul gas strainer and check valve.	3 mos
Perform chemical analysis of the oil. Record results.	3 mos
Change compressor oil filter element.	3 mos
Change oil system return filter.	3 mos
Inspect the nozzle and the oil return eductor for foreign particles.	3 mos
Check controls for safety cutouts. Confirm the integrity of the high- and low-pressure bellows of the oil pressure cutout system.	6 mos
Drain and replace oil in the compressor sump.	yr
Inspect and clean cooler, condenser, strainers, tubes, and end sheets.	yr

Table 11-1. Chilled water system (centrifugal chillers) (continued)

Chilled Water System (Centrifugal Chillers)	
Action	***Frequency***
Inspect and clean purge unit valves and orifices in the liquid feed line to the cooling coil and in the line connecting the purge exhaust line to the pressure switch. Drain and flush purge shell.	yr
Perform chemical analysis of the entire system.	yr
Megger compressor motor windings.	yr

Table 11-2. Chilled water system (pumps)

Chilled Water System (Pumps)	
Action	***Frequency***
Pumps (Off-Line)	
Clean and wipe down pump unit.	mo
Lubricate all operating equipment fitted with grease fittings.	mo
Inspect pump and seals for leaks. If leaking, repack (replace seals if mechanical type).	mo
Inspect valves and piping for leaks and corrosion. Repair leaks. Corroded surfaces shall be cleaned and repainted.	mo
Adjust valve stem packing if leaking. Replace packing as required.	mo
Inspect electrical wiring, connections, switches, and switch contacts. Repair or replace defective items as required. Tighten all connections. Check pump (motor) rotation.	mo
Inspect and repair damaged pipe insulation adjacent to pump installation.	mo
Tighten or replace loose, missing, or damaged nuts, bolts, or screws.	mo
Pumps (Operating)	
Upon energizing pump unit, observe and record suction and discharge pressures. Verify proper pump rotation and record data.	mo
Observe pump and motor operation. Note and record any undue vibration and noises that could indicate prospective malfunctions.	mo
Observe and record electrical load data on motor when under full load.	mo
Inspect shaft alignment and clearances of impeller and shaft. Readjust as required.	3 mos
Inspect drive couplings for wear and alignment.	3 mos
Adjust as required. Ensure that couplings are tight on shafts and are in alignment. Ensure coupling and shaft guards are in place.	as req'd
Replace mechanical pump seal.	yr

Table 11-3. Chilled water system (piping)

Chilled Water System (Piping)	
Action	***Frequency***
General	
Drain collecting tees and strainers.	mo
Check piping connections for leaks. Repair if needed.	mo
Check piping and equipment for rust spots. Determine cause of rust and repair as required. Clean and paint as required.	mo
Check for missing identification tags on equipment and piping.	mo
Check insulation to make sure it is not torn, missing, or degraded, and that it is still fastened to piping.	yr
Check pipe supports, hangers, and straps to make sure the piping is properly supported.	yr
Valves	
Check water valves for leaks. Correct defective conditions. Lubricate and tighten packing as necessary.	mo
Exercise all valves and grease stems (on os&y valves).	mo
CAUTION! BEFORE OPENING OR CLOSING ANY VALVE FOR MAINTENANCE, CONTACT YOUR AREA SUPERVISOR. BE SURE THAT THE VALVE CAN BE EXERCISED WITHOUT CAUSING ANY DAMAGE TO IT OR OTHER COMPONENTS.	
Control Valves	
Check for correct positioning and operation.	mo
Wipe valve operator rods clean and apply a thin coat or light oil.	mo
Adjust operator linkages and limit switches.	mo
Check electrical connections for loose, cracked, or frayed wires where applicable. Repair as required.	yr
Expansion Tanks	
Check tank for correct water level and air pressure charge. Check all fittings for leaks.	mo
Indicators	
Inspect all temperature and pressure indicators for cracked or broken covers, insecure mounting, and defective operation.	mo
Remove all indicators and test the accuracy.	yr

Table 11-3. Chilled water system (piping) (continued)

Chilled Water System (Piping)	
Action	***Frequency***
Strainers	
Check strainer for clogging. Clean if necessary.	week
Inspect strainer internals for wear. Replace if necessary.	yr
Chemical Pot Feeders	
Check operation of shutoff, bypass, and drain valves. Clean, repair, or replace as necessary.	3 mos
Close shutoff valves, open drain valve, and flush feeder with fresh water.	3 mos

Table 11-4. Refrigerant compressors used in thermal storage systems

Refrigerant Compressors Used In Thermal Storage Systems	
Action	***Frequency***
General	
Check oil levels both during operation and shutdown. Mark oil level on sight glass for reference.	day
Check sight glass for water accumulation.	day
Check the operating oil pressure and temperature. Adjust these as required to the compressor manufacturer's specifications.	week
Check suction and discharge pressures and temperatures.	week
Listen for unusual starting and operation noises.	week
Inspect all compressor gaskets for leaks. Be sure to open hermetic terminal box to check for leaks into the box. Check bolt torque or replace gaskets if you find any leaks.	week
Stop the compressor and inspect the oil level and condition of crankcase oil. Refill or replace oil when necessary. If the compressor has force-feed lubrication, check the oil pump pressure gauge.	mo
Inspect compressor motor for cleanliness, proper operation, and lubrication. When necessary, clean motor housing and lubricate motor bearings.	mo
Inspect the electrical circuit (including starter, controls, and compressor terminal box) for dirt and moisture. Clean and dry out if necessary.	3 mos
Inspect the condition of starter contacts and terminals. Dress or replace worn contacts. Clean and tighten terminals.	3 mos
Measure line voltage to compressor motor and balance between phases. Report abnormal conditions due to power source.	3 mos
Measure motor amperage draw. If above motor nameplate amperage, determine cause and repair.	3 mos
Test compressor protection devices for proper setting and operation. Adjust, repair, or replace if necessary.	3 mos
Check all compressor joints for refrigerant leaks, and check the purge unit for air and water leaks.	3 mos
Check the oil temperature and pressure cutouts for proper operation.	6 mos
Check safety controls for proper operation, including the chilled water and refrigerant low-temperature cutouts, condenser water high-pressure cutout, oil low-pressure cutout, and condenser water flow switches.	6 mos
Change the oil. If it becomes contaminated during machine repairs, it should be replaced. Replace the oil filter each time the oil is changed.	yr

Table 11-4. Refrigerant compressors used in thermal storage systems (continued)

Refrigerant Compressors Used In Thermal Storage Systems	
Action	***Frequency***
Inspect the bearings and replace them as necessary.	yr
Remove samples of refrigerant from the unit and have it analyzed by a competent laboratory. If the refrigerant is contaminated, consult with the unit's manufacturer for recommendations.	2 yrs
Centrifugal Compressors	
Keep the oil heater on during all compressor shutdowns.	as req'd
Check purge unit and its controls for proper operation, corrosion, and wear. Repair or replace as required.	3 mos
Reciprocating Compressors	
Keep the crankcase heater on during all compressor shutdowns.	as req'd
Inspect compressor drives for pulley alignment, belt tension, and condition of belts. Replace defective belts.	mo
Test for leaking compressor discharge and suction valves. Repair leaky valves.	3 mos
Disassemble compressor as necessary. Clean and repair parts. Replace defective parts. Regrind suction and discharge valves. Change the oil.	as req'd

Table 11-5. Refrigerant piping and accessories of thermal storage systems

Refrigerant Piping and Accessories of Thermal Storage Systems	
Action	***Frequency***
Refrigerant Piping	
Check the refrigerant piping for leaks and proper support. Repair defective connections.	3 mos
Check piping insulation to make sure the insulation is still wrapped around piping. Repair or replace if needed.	3 mos
Check piping for dents and frosting. Replace piping section if dents are found.	3 mos
Check piping for unnecessary vibration, noise, and wear. Repair and eliminate vibration and wear.	3 mos
Automatic Expansion Valves	
Check pressure on low side of valve to test for proper operation. Adjust valves when necessary.	3 mos
Thermostatic Expansion Valves	
Check the superheat of the expansion valve to see that it gives the proper control. Adjust, repair, or replace if necessary.	3 mos
Flooded Evaporator Float Valve	
Check the operation of the float valve to see that it gives the proper refrigerant level control in the evaporator. Repair or replace if not operating properly.	3 mos
Refrigerant Receivers	
Check the level of the refrigerant charge. Replenish the charge when necessary.	mo
Check the safety pressure relief valve or fusible safety plug to ensure that it is present and not damaged.	mo
Oil Traps and Separators	
Inspect the operation of the float valve. Clean the float assembly and adjust the float valve needle when necessary.	3 mos
Oil Receivers	
Check the operation of the float valve. Clean the float assembly and adjust when necessary.	3 mos
Take the receiver apart and clean the interior and exterior. Replace gaskets and worn or defective parts.	3 mos
Solenoid Valves	
Check the operation of the valve. Repair or replace if necessary.	mo
Check electrical connectors for loose, cracked, or frayed wires.	yr

Table 11-5. Refrigerant piping and accessories of thermal storage systems (continued)

Refrigerant Piping and Accessories of Thermal Storage Systems	
Action	***Frequency***
Suction Pressure Regulator, Hot Gas Bypass Valve, or Head Pressure Control Valve	
Test the regulator or valve for proper operation. Adjust regulator or valve as required. Repair or replace if inoperative.	mo
Filter-Dryers and Strainers	
Check strainers for clogging. Clean and replace if necessary.	mo
Replace filtering and drying material in filter-dryers that can be changed without taking the unit out of service.	yr
Refrigerant Valves	
Check refrigerant valves for leaks. Correct defective conditions. Lubricate packing when necessary.	mo
Check relief valve to be sure it is clean, unobstructed, and sealed properly.	mo
Sight Glass and Moisture Indicator	
Check the sight glass for signs of bubbles, indicating improper refrigerant charge. Add refrigerant if needed.	mo
Check the moisture indicator for signs of moisture, which is indicated by a color of the indicator. Install or replace dryer.	mo
Check for leaks around connectors. Repair if necessary.	mo
Hot Gas Muffler	
Check hot gas muffler for excessive noise or vibration. Replace if necessary.	mo
Pressure Gauges	
Inspect pressure gauges for cracked or broken covers, insecure mounting, and defective operation. Replace damaged or defective gauges.	mo
Remove pressure gauges and test accuracy.	yr

Table 11-6. Chilled water system instrumentation and electrical

Chilled Water System Instrumentation & Electrical	
Action	***Frequency***
Pneumatic Control Systems	
Check for air leaks in joints of piping and at control devices using soapy water, with control air compressor operating. Repair or replace parts as required.	3 mos
Check the contact surfaces and condition of all transmitters, sensing elements, temperature indicators, and pressure gauges.	3 mos
Check the operation of all control devices.	yr
Calibrate all controllers as recommended by the manufacturer of the control. Set the control point(s), sensitivity, range, proportional band, etc., to the correct values.	yr
Check the calibration of all transmitters, sensing elements, switches (temperature, pressure, flow, etc.), time delay relays, temperature and pressure indicators, and recorders. Clean, repair, or replace parts as needed. Calibrate the devices as necessary according to the manufacturer's instructions. Set the cut-in and cut-out points of all switches and time delay relays to the right value.	yr
Electronic and Electric Control Systems	
Check the main control panels for broken or frayed wires or loose connections.	3 mos
Check the contact surfaces and condition of all transmitters, sensing elements, temperature indicators, and pressure indicators.	3 mos
Check the contact and switch points in motor starters, relays, and switches to be sure that they are clean and meet properly. Clean or replace contacts and switches as needed.	6 mos
Check the operation of all control devices.	yr
Calibrate all controllers as recommended by the manufacturer of the control. Set the control point(s), sensitivity, range, etc., to the correct setting.	yr
Check the calibration of all transmitters, sensing elements, switches (temperature, pressure, flow, etc.), time delay relays, temperature and pressure indicators, and recorders. Clean, repair, or replace parts as needed. Calibrate the devices as necessary according to the manufacturer's instructions. Set the cut-in and cut-out points of all switches and time delay relays to the right value.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	

Table 11-6. Chilled water system instrumentation and electrical (continued)

Chilled Water System Instrumentation & Electrical	
Action	***Frequency***
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 12

DOMESTIC WATER SYSTEMS

12-1. Minimum maintenance activities for domestic water systems

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 12-1 provides maintenance information for domestic water systems. Table 12-2 provides maintenance information for reservoir water supply. Table 12-3 provides maintenance information for domestic water system instrumentation and electrical systems.

12-2. General maintenance procedures for domestic water systems

See the equipment manufacturer's data for specific instructions regarding maintenance of components associated with domestic water systems.

Table 12-1. Domestic water system

Domestic Water System	
Action	***Frequency***
Overall Domestic Water System	
Clean and inspect all of the components and piping associated with the domestic water system and report all discrepancies to supervisor. Inspect for:	
Leaking piping or equipment (gaskets, seals, packing, etc).	mo
Corrosion.	mo
Sagging or misaligned piping.	mo
Damaged flexible connectors or expansion joints.	mo
Loose equipment, piping, or electrical connections. (Correct during inspection if possible.)	mo
Incorrect level, temperature, or pressure gauge operation.	mo
Hot or noisy bearings, and equipment with unusual vibration or noise.	mo
Exercise all valves and perform routine maintenance as follows:	mo
Grease stems on OS&Y valves.	mo
Inspection packing gland and tighten as necessary.	mo
Verify correct position and operation.	mo
Check for leaking seals.	mo
Strainers	
Shut down associated equipment or open bypass valve where applicable. Isolate strainer and clean basket.	mo
Water Meter	
Remove meter head from the line and check the mechanism, and condition of the line and straightening vanes. Check for clogged or obstructed line or vanes.	yr
Check for water accumulation inside the meter. Replace seals when required.	yr
Check and clean all meter parts located in the flow stream. Make sure all moving parts spin freely.	yr
Check front bearing for excessive play. Replace when required.	yr
Lubricate register clock with light-weight oil and all other components fitted with grease fittings, with grease. DO NOT OVERLUBRICATE.	yr
Check meter indicator for proper operation. If parts such as gears and bushings are found to be worn out or bound, replace the indicator unit.	yr

Table 12-1. Domestic water system (continued)

Domestic Water System	
Action	***Frequency***
Pumps	
Inspect equipment and perform routine maintenance, and report all discrepancies to supervisor.	
Check for hot bearings.	week
Check for unusual noise or vibration.	week
Check tightness of fasteners (nuts, machine screws, set screws, shaft collars, etc.) and tighten as required.	mo
Visually inspect drive alignment.	mo
Lubricate bearings:	
Sleeve bearings.	mo
Ball bearings.	3 mos
Roller bearings.	mo
For units with belt drives inspect belts and pulleys.	mo
Measure belt tension and adjust as required.	mo
Check packing and adjust as required.	mo
Inspect internal components, replace as required, and adjust in accordance with manufacturer's recommendations.	yr
Reduced Pressure Backflow Preventer	
Isolate backflow preventer, disassemble, and carefully inspect all diaphragms, seals, and seating surfaces for damage or debris. Rinse all parts with clean water before reassembly.	yr
Test unit after servicing per manufacturer's instructions.	yr
Electric Water Heater	
WARNING! LOCATE POWER SOURCE BEFORE PROCEEDING WITH BREAKDOWN. OPEN CIRCUIT BREAKER. TAG WITH WHITE WARNING TAG TO PREVENT TAMPERING WITH CONTROLS.	
Drain tank and clean out sediment from bottom of tank.	yr
Remove and clean immersion type elements of electric storage heater.	yr
Cut gasket and reinstall elements.	yr
Remove and reinstall magnesium anode.	yr

Table 12-1. Domestic water system (continued)

Domestic Water System	
Action	***Frequency***
Fill water heater and inspect for leaks and check overall operation.	yr
Gas Water Heater	
CAUTION! LOCATE AND CLOSE GAS SHUTOFF VALVE BEFORE PROCEEDING WITH BREAKDOWN.	
Drain tank and clean out sediment from bottom of tank.	6 mos
Remove and clean gas burner.	6 mos
Inspect gas flue and report discrepancies to supervisor. Inspect for:	
Corrosion.	6 mos
Loose joints.	6 mos
Sagging or misaligned pipe.	6 mos
Fill water heater and inspect for leaks.	6 mos
Light pilot per manufacturer procedure. Observe for proper flame.	6 mos
Steam Water Heater	
CAUTION! LOCATE AND CLOSE STEAM SUPPLY SHUTOFF VALVE. ALLOW HEATER TO COOL BEFORE PROCEEDING WITH BREAKDOWN.	
Observe unit for proper operation.	3 mos
Check temperature gauge for proper reading, reset modulating valve as required.	3 mos
Check safety valve on open and closed position for proper operation.	3 mos
Inspect valves for proper operation. Clean and repack valves when necessary.	3 mos
Check all hangers and hanger brackets. Tighten loose parts.	3 mos
Inspect water, steam, and return piping for leaks. Repair as required. Replace leaking nipples and fittings.	3 mos
Clean steam traps and strainers.	6 mos
Check steam tube nest for leaks and repair when necessary.	6 mos
Check water heater and steam line insulation. Replace or repair any missing, loose, or worn insulation.	6 mos
Flush tank under pressure until water clears.	6 mos

Table 12-2. Reservoir water supply

Reservoir Water Supply	
Action	***Frequency***
Reservoir	
Drain reservoir and inspect for the following:	
Cracks.	yr
Infiltration of ground water due to deterioration of walls and floor.	yr
Scrub down all interior reservoir surfaces.	yr
Repair cracks and deteriorated surfaces.	yr
Flush down reservoir with clean water, exit, and close access covers.	yr
Reservoir Pump and Hydropneumatic Tank	
Check tank, pump, and piping for leaks.	mo
Operate pump and record the following:	mo
Pump on pressure.	mo
Pump off pressure.	mo
Cycle time from pump on to pump off.	mo

Table 12.3 Domestic water system instrumentation and electrical

Domestic Water System Instrumentation & Electrical	
Action	***Frequency***
Transmitters and Controllers	
Calibrate and adjust in accordance with the manufacturer's recommendations.	mo
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 13

CHEMICAL TREATMENT

13-1. Minimum maintenance activities for chemical treatment

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 13-1 provides maintenance information for all water systems (potable and process). Table 13-2 provides maintenance information for chemical feed systems with electric motor-driven reciprocating plunger metering pump. Table 13-3 provides maintenance information for chemical feed systems with water-powered piston action metering pump. Table 13-4 provides maintenance information for resin bed water softeners and dealkalizers. Table 13-5 provides maintenance information for resin bed ion exchange units. Table 13-6 provides maintenance information for chemical treatment systems instrumentation and electrical.

13-2. General maintenance procedures for chemical treatme nt

This section presents general instructions for maintaining the types of components associated with chemical treatment.

a. *Inspect chemical feed systems*. Start at the chemical feed tanks and follow the chemical feed system piping all the way to the points of end use. Inspect for:

(1) Leaking tanks and piping and/or corrosion

(2) Missing identification tags on system valves and components

(3) Sagging or misalignment of piping

(4) Adequate chemical solution levels in feed tanks to sustain treatment process until next inspection

(5) Proper readouts on instruments and gauges, and proper function of control system and feed system components

(6) Plugged or damaged piping

(7) Operating equipment making usual noises, vibrating excessively, or running hotter than normal

b. *Exercise valves*. Exercise all valves in the chemical feed system.

(1) Inspect packing gland and tighten if necessary.

(2) Check for correct positioning and operation.

(3) Check for leaking seals.

(4) Adjust operator linkages and limit switches on control valves.

c. Test alarms. Verify that the horns sound and all annunciator lights illuminate by pressing the appropriate test push buttons. Press the ACKNOWLEDGE and RESET push buttons when proper operation has been confirmed.

d. Chemical metering pump calibration. A common method of verifying the pumping rate of a metering pump is by means of a test tube calibration column. A typical test tube calibration column installation is shown on Figure 13-1. The pumping rate at a given setting is determined as follows.

(1) With the metering pump operating normally and the storage tank level higher than top of calibration column, open Valve B and allow the calibration column to fill.

(2) When the liquid level reaches the zero division mark, close Valve A and start timer. **Do not fill above the zero division mark.** (Note: Any division mark may be used as a starting point; however, filling to the zero mark allows a longer time interval which increases accuracy.)

(3) After a timed interval of not less than 30 seconds, note the reading on the calibration column and the time interval, and open Valve A and close Valve B.

(4) Determine pumping rate by dividing amount pumped by the time interval. (Note: Follow directions on calibration column to determine flow rate units.)

(5) Check the measured flow rate against the setting on the pump. If the actual flow rate is significantly different than the set flow rate, repeat Items 1 through 4 to confirm difference before taking action.

e. Clean all equipment. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

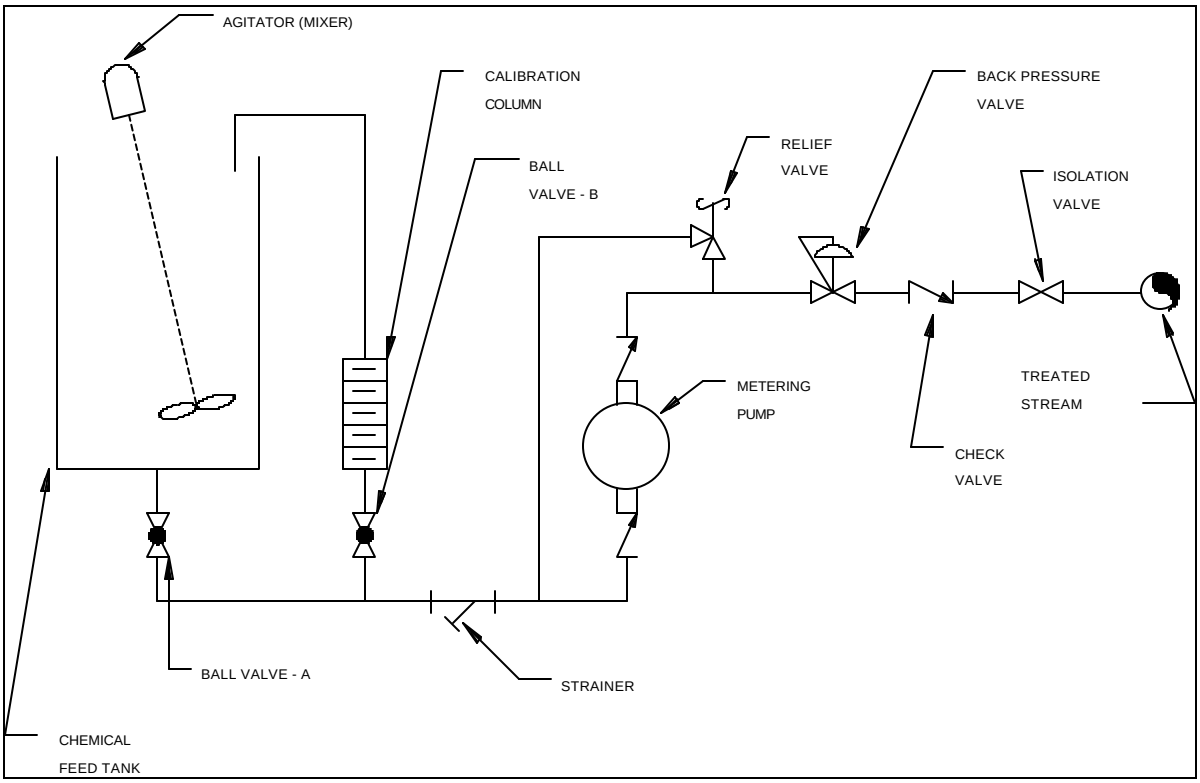

Figure 13-1. Typical test tube calibration column installation

Table 13-1. All water systems (potable and process)

All Water Systems (Potable and Process)	
Action	***Frequency***
Potable Water Supply and Reservoir	
Obtain samples at a number of locations throughout the potable water system and analyze for residual chlorine.	day
Adjust supply chlorinator unit as required to obtain desired residual chlorine level.	day
Operate potable water system recirculating chlorinator loop as required to obtain desired residual chlorine level in reservoir.	as req'd
Industrial Reservoir	
Obtain samples from the industrial reservoir and analyze for residual chlorine.	day
Operate industrial reservoir recirculating chlorinator loop as required to obtain desired residual chlorine level in reservoir.	as req'd
Chilled Water System (Closed)	
Obtain samples from the chilled water system and analyze for:	
Specific gravity (antifreeze concentration).	yr[1]
Corrosion inhibitor concentration (using chemical manufacturer recommended test kit).	yr[1]
pH.	yr[1]
Biological contamination and/or biological inhibitor concentration (using chemical manufacturer recommended test kit).	yr[1]
Dose system with appropriate chemicals or drain, flush, and refill system.	as req'd
Cooling Water Recirculating System (Closed Loop)	
Obtain samples from the hot water system and analyze for:	
Corrosion inhibitor concentration (using chemical manufacturer recommended test kit).	3 mos
pH.	3 mos
Biological contamination and/or biological inhibitor concentration (using chemical manufacturer recommended test kit).	3 mos
Dose system with appropriate chemicals or drain, flush, and refill system.	as req'd
Cooling Water Recirculating System (Open System)	
Obtain samples and analyze for:	
Total hardness [Ca - less than 900 ppm (as $CaCO_3$) and Si - less than 150 ppm].	day

Table 13-1. All water systems (potable and process) (continued)

All Water Systems (Potable and Process)	
Action	***Frequency***
Alkalinity (maintain between 120 and 125 ppm).	day
Corrosion inhibitor concentration (using chemical manufacturer recommended test kit).	week
pH.	week
Biological contamination and/or biological inhibitor concentration (using chemical manufacturer recommended test kit).	week
Dose system with appropriate chemicals or drain, flush, and refill system.	as req'd
Hot Water Heating Boiler (Closed Loop)	
Obtain samples from the hot water system and analyze for:	
Corrosion inhibitor concentration (using chemical manufacturer recommended test kit).	3 mos
pH.	3 mos
Biological contamination.	3 mos
Boiler – Hot Water and Steam	
Obtain samples of makeup water and analyze for total hardness and silica. Adjust operation of water treatment equipment (water softener, de-alkalizer, or ion exchange unit) to reduce hardness to 0.3 ppm (as $CaCO_3$) or less, and to reduce silica to 150 ppm or less.	shift
Steam Boiler	
Obtain samples of returned condensate and analyze for:	
Specific conductance (1,500 micromhos).	shift
pH.	shift
Obtain samples of feedwater and analyze for:	
Oxygen content (less than 5 ppm) or residual oxygen scavenger concentration (using manufacturer recommended test kit).	shift
Total hardness.	shift
pH (maintain between 8.5 and 9.5).	shift
Adjust chemical treatment.	as req'd

[1]Or anytime system has been open for maintenance

Table 13-2. Chemical feed system with electric motor-driven reciprocating plunger metering pump

Chemical Feed System with Electric Motor-Driven Reciprocating Plunger Metering Pump	
Action	***Frequency***
System	
Check level in chemical feed tank and refill as required.	day
Verify that pump is operating and lubricate pump packing.	day
Perform general inspection of system to verify that all components are operating properly and the system is not leaking. Clean strainer element or sludge separator as required.	day
Exercise all system valves and other components not routinely used in the operation	mo
Check calibration of metering pump. Clean check valves as required to maintain accuracy.	yr[1]
Drain chemical feed tank and piping. Thoroughly clean chemical feed tank and flush piping with an appropriate cleaning solution to remove deposits of chemicals.	yr
Metering Pump	
Lubricate pump packing with a lubricant compatible with the liquid being pumped.	day
Inspect packing for leaking and adjust or replace packing as required.	mo
Check gear box oil level and add oil as required.	mo
Change gear box oil. Clean gear box magnetic separator (or strainer, etc.).	6 mos
Lubricate drive motor in accordance with motor manufacturer's recommendations.	yr
Inspect check valves and clean as required. Clean with hot detergent solution and flush with fresh water.	as req'd
Chemical Feed Tank Mixer (Agitator)	
Check level and condition of grease in gear housing and grease as required. (Remove all old grease and pack with new grease any time unit is opened for repair.)	6 mos
Relief Valve	
Inspect valve and verify operation. Adjust, repair, or replace as required.	yr
Back Pressure Valve	
Inspect valve and verify operation. Adjust, repair, or replace as required. (May be required in systems where pump minimum system pressure required for accurate dispensing is greater than actual pressure of system.)	yr

[1]No less than yearly; properties of liquid pump may require more frequent checks.

Table 13-3. Chemical feed system with water-powered piston action chemical metering pump

Chemical Feed System with Water-Powered Piston Action Chemical Metering Pump	
Action	***Frequency***
System	
Check level in chemical feed tank and refill as required.	day
Verify that pump is operating.	day
Perform general inspection of system to verify that all components are operating properly and the system is not leaking. Clean strainer element or sludge separator as required.	day
Exercise all system valves and other components not routinely used in the operation.	mo
Check calibration of metering pump. Clean check valves as required to maintain accuracy.	yr[1]
Drain chemical feed tank and piping. Thoroughly clean chemical feed tank and flush piping with an appropriate cleaning solution to remove all deposits of chemicals.	yr
Water Meter	
See chapter 12 for a discussion of water meters and water meter maintenance.	
Metering Pump	
Inspect check valves and integral suction strainer, and clean as required. Clean with hot detergent solution and flush with fresh water. As required to maintain chemical flow and pump accuracy.	as req'd

[1]No less than yearly; properties of liquid pump may require more frequent checks.

Table 13-4. Resin bed softeners and dealkalizers

Resin Bed Softeners and Dealkalizers	
Action	***Frequency***
Discharge Water Hardness	
Obtain water samples of unit discharge and test for hardness.	day
Based on sample results, adjust brine used for each regeneration cycle, the number of cycles per week and the regeneration time of day to achieve the desired hardness.	as req'd
Record regeneration cycle schedule changes and post at the equipment.	as req'd
Electrolyte Level	
Check electrolyte level. Add additional electrolyte (salt for softener units, stronger caustic or acid for dealkalizer units) as required.	day
Inlet Water Hardness	
Obtain water samples of water supplied to unit and test for hardness.	week
Use results to adjust unit operation for seasonal changes in feedwater quality.	as req'd
Controller Clock	
Verify operation and control settings.	week
Unit Controls	
Verify operation of regeneration controls and devices. Rotate the controller unit through a full cycle (Backwash, Rinse, Flush, and In-Service) and observe operation.	week
Electrolyte Tank Water Level	
Check tank for proper water level.	week

Table 13-5. Resin bed ion exchange unit

Resin Bed Ion Exchange Unit	
Action	***Frequency***
Water Quality	
Verify that the resistivity of the discharge water is within specifications.	day
Verify the controller is starting and stopping the regeneration cycles as required.	day
Acid Electrolyte	
Verify that there is enough acid electrolyte for the next regeneration cycle.	as req'd[1]
Caustic Electrolyte	
Verify that there is enough caustic electrolyte for the next regeneration cycle. After each regeneration cycle.	as req'd[1]
Water Hardness Testing	
Test the hardness of the discharge of the anion column (caustic electrolyte) during a regeneration cycle. Adjust electrolyte strength as required.	6 mos[2]
Water Hardness	
Verify the condition of the anion column resin bed by a test for hardness. If hydroxide hardness is high, a special acid wash cycle may be required. Consult manufacturer's literature.	as req'd[3]
Regeneration	
Verify that the regeneration controls and devices are operating properly. Rotate the control unit through a full cycle (Backwash, Rinse, Flush, and In-Service) and observe operation.	week

[1] After each regeneration cycle.
[2] 6 months or if acid electrolyte is exhausted.
[3] As required to maintain water quality.

Table 13-6. Chemical treatment systems instrumentation and electrical

Chemical Treatment Systems Instrumentation & Electrical	
Action	***Frequency***
Level Gauges	
Check for accuracy. Recalibrate as required following equipment manufacturer's instructions.	yr
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Control Switch	
Check with a meter or a test light temporarily clipped across the switch. Simulate a trip condition. Switch should operate within 10 percent of desired control action set point.	yr
pH Probes	
Remove probe from line and rinse with fresh water. Calibrate pH unit in accordance with manufacturer's recommendations.	week
Conductivity Probes	
Remove probe from line and rinse with fresh water. Calibrate conductivity unit in accordance with manufacturer's recommendations.	week
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 14

AIR HANDLING SYSTEMS

14-1. Minimum maintenance activities for air handling systems

The tables located at the end of this chapter indicate items which must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 14-1 provides maintenance information for air handling units. Table 14-2 provides maintenance information for package air conditioning (DX) units. Table 14-3 provides maintenance information for air handling system instrumentation and electrical.

14-2. General maintenance procedures for air handling systems

This section presents general instructions for maintaining a typical air handling system.

a. *Inspect air handling systems*. Inspect for the following.

(1) Obstructions to air paths

(2) Obstructions to the face area of coils

(3) Dirty strainers (high pressure drop)

(4) Damage to or deterioration of equipment housings, fan housings, ducts, expansion joints, etc., that would let air leak from the system.

(5) Damage to, or deterioration of, ducts, flexible connections, and other components that would allow air to leak into occupied spaces.

(6) Obstructions in dampers, isolation valves, and device operators that would prevent free movement of the device.

(7) Deformed flexible piping connections and expansion joints

(8) Misaligned or sagging pipe and duct sections

(9) Deformed or broken pipe and duct support devices. (Verify that support devices designed to accommodate movement of the duct are free to operate.)

(10) Unusual noise, vibration, or overheating

(11) Loose mechanical or electrical connections

(12) Missing components

(13) Misalignment of drives, worn belts and pulleys, and loose drive belts on belt-driven equipment

(14) Damaged or missing equipment guards

(15) Damaged or missing insulation

(16) Damaged or missing equipment tags

b. Exercise remote-operated dampers and valves. Exercise all remote-operated dampers and valves.

(1) Verify free operation of dampers and valves.

(2) Inspect any packing glands, and tighten as necessary.

(3) Check for leaking seals.

(4) Wipe damper and valve operators clean, apply a light coat of protective oil to exposed operating shafts, and lubricate bearings and pinned connections.

(5) Adjust operator linkages for proper valve positioning, and adjust limit switches for proper position indication.

c. Test alarms. Verify operation of system alarms and alarm system by actuating appropriate system test push buttons. Verify that the audible alarm sounds and that all warning and annunciator lights operate.

d. Rotating equipment clearance adjustment. After long service, the running clearances in some types of rotating equipment (fans, pumps, compressors, etc.) may increase to the point where the device is losing capacity or pressure. Resetting the clearances will normally improve performance. Check clearances during annual inspections and adjust as required. Refer to the manufacturer's technical service manual.

e. Examine internal parts of rotating equipment. Periodically (at least annually) remove casing access covers and inspect components for wear. Replacing a relatively inexpensive part after only moderate wear can eliminate the need to replace more expensive parts at a later date. Refer to manufacturer's technical service manual.

f. Clean all equipment. Clean all equipment regularly. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

Table 14-1. Air handling unit

Air Handling Unit	
Action	***Frequency***
WARNING! BEFORE BEGINNING ANY MAINTENANCE. DISCONNECT ELECTRICAL POWER TO THE AIR HANDLING UNIT. LOCK OUT AND TAG SWITCH AT MCC.	
Enclosure and Access Doors	
Inspect the enclosing cabinet, isolators, and supporting structures. Tighten loose bolts and fasteners. Ensure that access door gaskets are effective; if not, replace.	mo
Filters	
Check filters. Replace as required.	mo
Coils	
Inspect for leads and corrosion. Repair or replace as required. Check for dirty coils. Clean as required; wash or blow clean with inert gas or compressed air.	mo
Drain Pan	
Clean condensate drain pan, drain connection, and piping. Brush or blow drain lines clean.	mo
Fans	
Check for hot bearings.	week
Check for unusual noise or vibration.	week
Check tightness of fasteners (nuts, machine screws, set screws, shaft collars, etc.) and tighten as required.	mo
Visually inspect drive alignment.	mo
Lubricate bearings:	
Sleeve bearings.	mo
Ball bearings.	3 mos
Roller bearings.	mo
For units with belt drives inspect belts and pulleys.	mo
Measure belt tension and alignment; adjust as required.	mo
Inspect fan blades (or fan wheel) for buildup of dirt or scale, use soft brush or clean rags to loosen or remove dirt, and flush surfaces with clean water.	mo

Table 14-1. Air handling unit (continued)

Air Handling Unit	
Action	***Frequency***
CAUTION! SOME FANS MAY HAVE INTERNAL COMPONENTS PROTECTED WITH CORROSION-RESISTANT COATINGS WHICH CAN BE EASILY DAMAGED. DO NOT USE CLEANING TOOLS OR MATERIALS THAT WILL DAMAGE COATINGS.	
Inspect components and repair or replace as required. This includes repairing defects in protective coatings. If work performed on fan wheel, check balance and rebalance as required.	yr
Dampers	
Inspect damper assemblies, and report all discrepancies to supervisor. Inspection shall include:	
Verify damper position relative to facility mode of operation. Adjust position indication switches as required.	week
Exercise dampers to verify free operation; repair or adjust as required.	mo
Inspect seals and seal contacting surfaces for full contact; adjust seals and/or repair seals and seal contacting surfaces as required.	mo
Wipe clean damper operator and connecting linkages; apply a light coat of oil.	mo
Clean and inspect bearings; lubricate and adjust bearings as required.	mo
Operated Valves	
Verify valve position relative to facility mode of operation. Adjust position indication switches as required.	week
Clean rods on valve operator and apply a light coat of protective oil.	mo
Inspect seals.	mo
Inspect and tighten packing as required.	mo
All Valves	
Exercise all valves and perform routine maintenance, and report all discrepancies to supervisors.	
Grease stems on OS&Y valves.	mo
Inspect packing gland and tighten as necessary.	mo
Verify correct position and operation.	mo
Check for leaking seals.	mo

Table 14-2. Package air conditioning (DX) unit

Package Air Conditioning (DX) Unit	
Action	***Frequency***
WARNING! BEFORE BEGINNING ANY MAINTENANCE, DISCONNECT ELECTRICAL POWER TO THE UNIT. LOCK OUT AND TAG SWITCH AT MCC.	
Enclosure	
Inspect the enclosing cabinet, isolators, and supporting structures. Tighten loose bolts, fasteners, and anchors.	4 mos
Filters	
Check filters. Replace as required.	mo
Coils and Piping	
Inspect refrigeration circuit for oil and refrigerant leaks with halide torch or electronic leak detector. Correct deficiencies. Check refrigerant charge and lubricating oil levels. Recharge and add oil as required.	4 mos
Drain Pan	
Clean condensate drain pan, drain connection, and piping. Brush or blow drain lines clean.	4 mos
Fans	
Check for hot bearings.	4 mos
Check for unusual noise or vibration.	4 mos
Check for tightness of fasteners (nuts, machine screws, set screws, shaft collars, etc.) and tighten as required.	4 mos
Lubricate bearings:	
Sleeve bearings.	mo
Ball bearings.	3 mos
Roller bearings.	mo
For units with belt drives, inspect belts and pulleys.	4 mos
Measure belt tension and alignment; adjust as required.	4 mos
Inspect fan blades (or fan wheel) for buildup of dirt or scale, use soft brush or clean rags to loosen or remove dirt, and flush surfaces with clean water.	4 mos

Table 14-2. Package air conditioning (DX) unit (continued)

Package Air Conditioning (DX) Unit	
Action	***Frequency***
CAUTION! SOME FANS MAY HAVE INTERNAL COMPONENTS PROTECTED WITH CORROSION RESISTANT COATINGS WHICH CAN BE EASILY DAMAGED. DO NOT USE CLEANING TOOLS OR MATERIALS THAT WILL DAMAGE COATINGS.	
Inspect internal components and repair or replace as required. This includes repairing defects in protective coatings. If work performed on fan wheel, check balance and rebalance as required.	yr
Dampers	
Inspect damper assemblies, and report all discrepancies to supervisor. Inspection shall include:	
Verify damper position relative to facility mode of operation. Adjust position indication switches as required.	4 mos
Exercise dampers to verify free operation; repair or adjust as required.	4 mos
Inspect seals and seal contacting surfaces for full contact; adjust seals and/or repair seals and seal contacting surfaces as required.	4 mos
Wipe clean damper operator and connecting linkages; apply a light coat of oil.	4 mos
Clean and inspect bearings; lubricate and adjust bearings as required.	4 mos
Compressor and Condenser Fan	
Observe and record the following:	
Compressor head pressure.	4 mos
Compressor suction pressure.	4 mos
Compressor oil pressure.	4 mos
Compressor temperature.	4 mos
Compressor motor amperage.	4 mos
Compressor motor voltage.	4 mos
Fan motor amperage.	4 mos
Fan motor voltage.	4 mos
Controls	
Clean and inspect all control devices, safety devices, thermostats, and similar devices. Calibrate and adjust all devices as required.	4 mos

Table 14-2. Package air conditioning (DX) unit (continued)

Package Air Conditioning (DX) Unit	
Action	***Frequency***
Pumps	
Inspect equipment and perform routine maintenance, and report all discrepancies to supervisor.	
Check for hot bearings.	week
Check for unusual noise or vibration.	week
Check tightness of fasteners (nuts, machine screws, set screws, shaft collars, etc.) and tighten as required.	mo
Visually inspect drive alignment.	mo
Lubricate bearings:	
Sleeve bearings.	mo
Ball bearings.	3 mos
Roller bearings.	mo
For units with belt drives, inspect belts and pulleys.	4 mos
Measure belt tension and adjust as required.	4 mos
Check packing and adjust as required.	mo
Inspect internal components, replace as required, and adjust in accordance with manufacturer's recommendations.	yr

Table 14-3. Air handling system instrumentation and electrical

Air Handling System Instrumentation & Electrical	
Action	***Frequency***
Transmitters and Controllers	
Calibrate and adjust in accordance with the manufacturer's recommendations.	mo
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 15

INDUSTRIAL WATER SUPPLY SYSTEMS

15-1. Minimum maintenance activities for industrial water supply systems

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 15-1 provides maintenance information for vertical turbine pumps. Table 15-2 provides maintenance information for general system maintenance. Table 15-3 provides maintenance information for industrial water supply system instrumentation and electrical.

15-2. General maintenance procedures for industrial water supply systems

This section presents general instructions for maintaining the types of components associated with industrial water supply systems.

a. Plate and frame heat exchanger maintenance. Since heat exchangers have no moving parts, heat exchanger maintenance problems generally result from poor water quality and lack of proper water treatment. Another cause of maintenance problems is temperature and pressure cycling as equipment is started and stopped. Heat exchangers are subject to fouling or scaling. A light sludge or scale coating on heat transfer surfaces can greatly reduce the effectiveness of the heat exchanger. This loss of performance may show up as higher than design temperatures or higher than design pressure drops through the heat exchanger unit. Units require periodic cleaning to maintain performance.

(1) The interior plates of the heat exchanger can be cleaned by the following methods.

(a) Open the unit in accordance with manufacturer's instructions.

(b) Each plate should be cleaned separately. Depending on the amount of cleaning to be performed, the plate can be cleaned while still hanging in the unit or removed and placed on a flat surface and cleaned.

(c) **Never use a steel brush or steel wool on the plates.** If a brush is required, a fiber type is recommended. If iron is forcibly rubbed on a stainless steel surface, it is impossible to remove all imbedded particles and will result in accelerated rusting and/or corrosion. If it is absolutely necessary that a steel brush be used, a brush material compatible with the plate material, such as stainless steel, is recommended.

(d) Be careful not to scratch the gasket surfaces.

(e) After brushing, each plate should be rinsed with clean water.

(f) **The gaskets must be wiped dry with a dry cloth.** Solid particles adhering to the gaskets can cause damage and may result in leakage when the unit is put back in operation.

(g) The lower portion of each plate should be inspected carefully and cleaned appropriately as this is the primary area where residual solid material tends to accumulate.

(h) Wipe off the mating surface, i.e., the rear of the plate where the gasket seats.

(i) Upon completion of cleaning and final inspection of each plate, the unit may be closed and tightened per manufacturer's assembly drawing and tightening instructions, and put back into operation.

(j) Precipitates of calcium compounds from cooling water and other sources can be removed by wetting the plate at room temperature with a solution of nitric acid [1 volume concentrated Nitric Acid (specific gravity 1.41) to 9 volumes of water]. Let stand for approximately 5 to 10 minutes, water rinse, and then fiber brush. If necessary, repeat this operation several times. An alternate cleaner is Oakite 131 (inhibited phosphoric acid) at up to 150°F. Upon completion of acid treatment, neutralize with a dilute caustic solution followed by a clean water rinse. If the above methods are not effective, there are many commercial chemical cleaning programs available. Carefully follow the manufacturer's instructions as these programs generally use an acid or caustic wash that must be neutralized to prevent long-term attack on heat transfer surfaces or interference with water chemical treatment programs.

(2) When opening or disassembling a heat exchanger for inspection or maintenance, observe the following.

(a) The pressure of both liquids should be simultaneously decreased gradually when shutting down the unit.

(b) Exercise care in handling plates to avoid damage. Do not handle plates with hooks or other sharp tools which might cause damage. A skid, cradle, or other protective device should be used when available.

(c) Thoroughly clean plates at each cleaning. Leaving any film on the plates only decreases the time interval to the next cleaning. Wire brushes and scrappers may be used to assist in cleaning the cooling water (usually the outside) of tubes. Exercise care to minimize damaging the tube surfaces.

(d) Inspect plates for damage and repair as required.

(e) When reassembling the unit, do not tighten bolts on gasketed connections until the gaskets have been properly seated. Replacing the gaskets when the unit is reassembled can eliminate having to schedule another shutdown to replace a leaking gasket. Composition gaskets become brittle and dried out and do not provide an effective seal when reused. Metal or metal jacketed gaskets when compressed initially tend to match the gasket contact surfaces and become work-hardened. When reassembled, the joint may not make up the same and a work-hardened gasket will not conform to the mating surfaces. The joint may leak and the mating surfaces may be damaged.

(f) When a new or repaired unit is placed in service, frequently inspect all gasketed joints during the first two days of operation for leaking joints or loose bolts. Tighten and adjust as required.

b. Test alarms. Verify operation of system alarms and alarm system by actuating appropriate system test push buttons. Verify that the audible alarm sounds and that all warning and annunciator lights operate.

c. Rotating equipment clearance adjustment. After long service, the running clearances in some types of rotating equipment (fans, pumps, compressors, etc.) may increase to the point where the device is

losing capacity or pressure. Resetting the clearances will normally improve performance. Check clearances during annual inspections and adjust as required. Refer to the manufacturer's technical service manual.

d. *Examine internal parts of rotating equipment.* Periodically (at least annually) remove casing access covers and inspect components for wear. Replacing a relatively inexpensive part after only moderate wear can eliminate the need to replace more expensive parts at a later date. Refer to manufacturer's technical service manual.

e. *Clean all equipment.* Clean all equipment regularly. Clean equipment is easier to inspect, lubricate and adjust. Clean equipment also runs cooler and looks better.

Table 15-1. Vertical turbine pumps

Vertical Turbine Pumps	
Action	***Frequency***
Pumps (Not Operating)	
Tighten or replace loose, missing, or damaged nuts, bolts, or screws.	yr
Remove rust or corrosion with a fine wire brush and rags. Clean all parts, except electrical contacts, by moistening a cloth or brush with a suitable solvent.	6 mos
Lubricate motor bearings.	6 mos
Grease guide bearings. Clean all dirt from fittings and remove relief plugs. Purge bearings using a low pressure grease gun until new grease appears at relief hole.	6 mos
Check electrical insulation for cracks, cuts, and abrasions.	6 mos
Pumps (Operating)	
Observe and record suction and discharge pressures.	yr
Observe and record electrical load data on motor when under full load.	yr
Replace mechanical pump seal.	yr
While pump is running, inspect for proper rotation, vibration, noise, output, etc.	6 mos
Ensure pump does not run backwards when it shuts off. This will indicate if the check valve is functioning properly.	6 mos
Check automatic operation of pump.	6 mos
Industrial Reservoir	
Check residual chlorine level in the industrial reservoir. Should be approximately 1 ppm. Add chlorine as required, or drain reservoir and add fresh water until residual chlorine level is approximately 1 ppm.	day

Table 15-2. General system maintenance

General System Maintenance	
Action	***Frequency***
General	
Inspect entire industrial water system for the following:	
Leaking pipe joints and/or corrosion.	mo
Torn or missing identification tags.	mo
Proper pipe support (sagging or misalignment).	mo
Condition of flexible joints.	mo
Valves	
Exercise all valves:	
Grease stems on os&y valves.	mo
Inspect packing gland and tighten if necessary.	mo
Control Valves	
Check for correct positioning and operation of control valves.	yr
Check for leaking seals.	yr
Wipe valve operator rods clean and apply coat of light oil.	yr
Adjust operator linkages and limit switches as required.	yr

Table 15-3. Industrial water supply system instrumentation and electrical

Industrial Water Supply System Instrumentation & Electrical	
Action	***Frequency***
Pneumatic Control Systems	
Check for air leaks in joints of piping and at control devices using soapy water, with control air compressor operating. Repair or replace parts as required.	3 mos
Check the contact surfaces and condition of all transmitters, sensing elements, temperature indicators, and pressure gauges.	3 mos
Check the operation of all control devices.	yr
Calibrate all controllers as recommended by the manufacturer of the control. Set the control point(s), sensitivity, range, proportional band, etc., to the correct values.	yr
Check the calibration of all transmitters, sensing elements, switches (temperature, pressure, flow, etc.), time delay relays, temperature and pressure indicators, and recorders. Clean, repair, or replace parts as needed. Calibrate the devices as necessary according to the manufacturer's instructions. Set the cut-in and cut-out points of all switches and time delay relays to the right value.	yr
Electronic and Electric Control Systems	
Check the main control panels for broken or frayed wires or loose connections.	3 mos
Check the contact surfaces and condition of all transmitters, sensing elements, temperature indicators, and pressure indicators.	3 mos
Check the contact and switch points in motor starters, relays, and switches to be sure that they are clean and meet properly. Clean or replace contacts and switches as needed.	6 mos
Check the operation of all control devices.	yr
Calibrate all controllers as recommended by the manufacturer of the control. Set the control point(s), sensitivity, range, etc., to the correct setting.	yr
Check the calibration of all transmitters, sensing elements, switches (temperature, pressure, flow, etc.), time delay relays, temperature and pressure indicators, and recorders. Clean, repair, or replace parts as needed. Calibrate the devices as necessary according to the manufacturer's instructions. Set the cut-in and cut-out points of all switches and time delay relays to the right value.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos

Table 15-3. Industrial water supply system instrumentation and electrical (continued)

Industrial Water Supply System Instrumentation & Electrical	
Action	***Frequency***
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 16

COMPRESSED AIR SYSTEMS

16-1. Minimum maintenance activities for compressed air systems

The tables that follow indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Frequencies listed are typical for mid-life equipment that has been well maintained. Users may need to modify the frequencies to reflect factors such as the age and condition of equipment at the facility, and the physical arrangement of the facility.

16-2. General maintenance procedures for compressed air systems

The facility operator should use the following action sheets as a guide in conjunction with the maintenance manuals to develop a comprehensive maintenance plan for the facility. Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 16-1 provides maintenance information for compressors. Table 16-2 provides maintenance information for compressed air systems. Table 16-3 provides maintenance information for compressed air starting systems. Table 16-4 provides maintenance information for compressed air system instrumentation and electrical.

16-3. General instructions

This section presents general instructions for maintaining the types of compressors found at Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) sites.

a. Inspect compressed air system. Start at the compressor air intakes and follow the compressed air system piping all the way to the points of end use. Inspect for the following.

(1) Leaking pipe joints and/or corrosion

(2) Missing identification tags on system valves and components

(3) Sagging or misalignment of piping

(4) Compressed air leaks (use a sonic leak detector)

(5) High-pressure drops across valves and equipment

(6) Drive misalignment and worn drive components

(7) High temperatures

(8) Dirty heat transfer surfaces

(9) Plugged strainers, filters, and drains

(10) Excessive oil and water in clean air streams

b. Exercise valves. Exercise all valves in the compressed air system.

(1) Inspect packing gland and tighten if necessary.

(2) Check for correct positioning and operation.

(3) Check for leaking seals.

(4) Adjust operator linkages and limit switches on control valves.

c. Test alarms. Verify that the horns sound and all annunciator lights illuminate by pressing the appropriate test push buttons. Press the ACKNOWLEDGE and RESET push buttons when proper operation has been confirmed.

d. Inspect air dryer for proper operation. Obtain an operating and maintenance manual from the manufacturer of the equipment installed and follow manufacturer's recommendations. Include inspection of any pre-filter and after-filter elements as part of the dryer inspection.

Table 16-1. Compressors

Compressors	
Action	***Frequency***
Compressor Intake Air Filter	
Verify intake air filter is free of obstructions.	week
For viscous and dry type air filters, check pressure drop across filter and clean or replace as required.	week
For oil bath type filters:	
Check level of oil in bath and add oil as required.	week
Determine level of dirt in sump and remove if required (may require draining and replacing oil.	week
Area Around Compressor	
Verify that there is enough clear area around the compressor for adequate ventilation and the area is free of stored materials and debris that may interfere with the operation of the compressor.	week
Compressor Assembly	
Visually inspect the entire unit for loose connections, pulleys, couplings, leaks, etc.	week
Visually inspect leveling and drive alignment, and check tightness of all mounting bolts.	week
Verify all guard devices (belt, shaft, etc.) for tightness and proper clearance.	week
Check for any unusual noise, vibration, or overheating.	week
For belt-driven compressors, inspect belts for proper tension adjustment, drive alignment, and belt wear and replace as required.	week
For units with rotating or sliding bearings requiring lubrication (grease), lubricate bearings:	
Outdoor or portable.	mo
Indoor stationary.	3 mos
For units with lubricating oil systems:	
Check the oil level and add oil as required.	week
Change oil. (If not specified by equipment manufacturer, after 1,000 hours of operation or every 3 months, which occurs first.)	per mfg
For air cooled compressors, clean cooling surfaces by brushing, and wiping with a clean rag.	week
For water-cooled compressors, verify coolant flow and adjust flow as required.	week

Table 16-1. Compressors (continued)

Compressors	
Action	***Frequency***
Electric Motor Drives	
Check electric motor for excessive vibration or overheating, and compare operating current under load against nameplate current rating.	week
Verify that motor ventilation openings are clear; clean dirt off of motor and wipe off any moisture or grease on external surfaces.	week
For motors with bearings requiring lubrication, lubricate bearings. (If no specific manufacturer's recommendation, annually.)	per mfg
Diesel or Gasoline Engine Drives	
Monitor lube oil temperature and pressure and log as required.	hr
Monitor cooling system temperature and log as required.	hr
Check level in lube oil sump and add oil as required.	day
Check level in cooling system and add coolant as required.	day
Check engine coolant for proper level of antifreeze and corrosion inhibitors and add antifreeze and corrosion inhibitors as required.	mo
Lubricate (grease) engine and ancillary component bearings.	mo
Take lube oil sample and test for fuel contaminant level.	week
Take lube oil sample for analysis by the Army Oil Analysis Program (AOAP).	mo/250 hrs
Check pressure drop across lube oil filter and replace filter as required. (If pressure gauges not installed, replace at interval recommended by equipment manufacturer. If no equipment manufacturer's recommendation, replace with each lube oil change.)	day
Change lube oil. (Or, change at interval recommended by equipment manufacturer. If no manufacturer's recommendation, 1,000 hours of operation or every 3 months, whichever occurs first.)	per mfg
Engine air intake air filters:	
Inspect filter and service as required.	week
Clean or replace filter as required. (Or, if no manufacturer's recommendation, at every lube oil change.)	per mfg

Table 16-2. Compressed air systems

Compressed Air Systems	
Action	***Frequency***
System	
Start at the air intake to the compressor. Follow the compressed air system to each point of use. Inspect for, and report all discrepancies to, supervisor:	
Leaking pipe joints.	day
Leaking equipment (heat exchangers, air dryers, receivers, etc.).	day
Leaking packing glands and seals.	day
Incorrect system pressures or temperatures	day
Blocked or plugged drains.	day
Clean equipment, brush off loose dirt or debris, and wipe off moisture and oil.	mo
Manual Valves	
Exercise all valves and report all discrepancies to supervisor. Exercise shall include the following activities:	
Grease stems of OS&Y valves.	mo
Inspect packing gland and tighten if necessary.	mo
Check for correct position and operation.	mo
Check for leaking seals.	mo
Safety Relief Valves	
Verify safety relief valve operation by opening valve for a few seconds using the test lever (very little force should be required to open the valve using the test lever; if excessive effort is required, valve requires rebuild and adjustment).	6 mos
WARNING! THIS OPERATION REQUIRES HEARING PROTECTION AND A FULL-FACE SHIELD.	
Remove, rebuild, adjust, and recertify valve set pressure.	yr
All Strainers, Separators and Filters	
Verify that automatic trap is functioning and drain is clear; for manual drain system, drain reservoirs.	day
For particulate filters, check pressure drop across filter and clean or replace filter element as required.	week
For coalescing filters, check pressure drop across filter and visually inspect for indication that filter element is saturated and clean or replace filter element as required.	week

Table 16-2. Compressed air systems (continued)

Compressed Air Systems	
Action	***Frequency***
Receivers	
Inspect receiver and report all discrepancies to supervisor. Inspection shall include checking for:	
Verify that automatic trap is functioning and drain is clear; for manual systems, drain water. (Variable – frequency depends on operation experience.)	day
Air or moisture leaks and corrosion.	mo
Excessive moisture on floor below drain valves.	mo
Control Valves, Diaphragm Operator Force Balance	
Inspect all control valves and adjust as required, or note for future maintenance. Report all discrepancies to supervisor. Inspection shall include checking for:	
Air leaks.	mo
Erratic air pressure at inlet or outlet.	mo
Actual pressure compared to pressure setting of valve.	mo
Inter-coolers and After-coolers	
For air-cooled units:	
Verify cooling surfaces are clear of debris (waste paper, rags, packing material, etc.); clean area as required.	week
Verify cooling surfaces do not have heavy accumulations of dirt, oil, or grease; clean surfaces as required.	week
For units with electric fans, verify operation of fan, and visually inspect fan for:	
Excessive noise, vibration, or overheating.	week
Guards in place with proper clearances.	3 mos
Lubricate fan as required.	as req'd
For water-cooled units:	
Check inlet and outlet air and coolant temperatures and adjust coolant flow as required.	week
Check pressure drop across air side and water side of unit.	week
Visually inspect units for leaks or corrosion and report discrepancies to supervisor.	mo
Low Point Distribution Piping Drains	
For low point drains with automatic traps clean element in any strainer ahead of the trap; cleaning may be accomplished by slowly opening and closing the blowdown valve on the strainer. Do not complete valve closing until all water is drained.	mo

Table 16-2. Compressed air systems (continued)

Compressed Air Systems	
Action	***Frequency***
NOTE! EXCESSIVE WATER DISCHARGE MAY INDICATE THAT THE TRAP IS NOT OPENING AND REQUIRES MAINTENANCE.	
Verify that the trap drain line is clear.	mo
Drain the dirt leg by slowly opening and closing the dirt leg drain valve. Do not complete valve closing until all water is drained.	mo
Air Dryer	
General checks and inspections should be performed to verify or determine:	
Drains, if present, are clear.	day
Automatic traps are functioning.	day
Any external coolant streams are properly adjusted.	week
Operating pressure drops, and air and coolant stream temperatures are within normal ranges.	week
Motor-driven equipment operating without excessive noise or vibration, and motor is not overheating.	week

Table 16-3. Compressed air starting system

Compressed Air Starting System	
Action	***Frequency***
System	
Perform all applicable maintenance actions for compressors and compressed air systems from tables 16-1 and 16-2.	as req'd
Starting Air Lubricator	
Check oil level. When lubricator becomes half empty, fill reservoir with oil.	week
CAUTION! NEVER ALLOW THE AIR LUBRICATOR RESERVOIR TO BECOME EMPTY. THE STARTING MOTOR WILL BE DAMAGED BY LACK OF PROPER LUBRICATION.	
Adjust lubricator drip rate in accordance with manufacturer's recommendation (typically 3 to 4 drops per minute when the air motor is operating).	mo
Starting Air Strainer	
Remove, thoroughly clean, and reinstall strainer element.	3 mos
Air Motor	
Service in accordance with manufacturer's recommendations. Servicing shall include flushing air motor with approved cleaning agent to remove accumulated dirt, water, oily residues, etc.	yr

Table 16-4. Compressed air system instrumentation and electrical

Compressed Air System Instrumentation & Electrical	
Action	***Frequency***
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 17

PNEUMATIC CONTROLS

17-1. Minimum maintenance activities for pneumatic controls

The tables that follow indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment.

17-2. General maintenance procedures for pneumatic controls

Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 17-1 provides maintenance information for air compressors and piping. Table 17-2 provides maintenance information for pneumatic control system instrumentation and electrical.

Table 17-1. Air compressor and piping

Air Compressor and Piping	
Action	***Frequency***
WARNING! BEFORE BEGINNING ANY MAINTENANCE ON THE AIR COMPRESSOR, DISCONNECT ELECTRICAL POWER, LOCKOUT AND TAG SWITCH AT MCC.	
Air Compressor and Lines	
Check oil pressure.	day
Check oil level:	
1 hp	week
¼ through ¾ ph	mo
Check percent on-time.	mo
Check air distribution system for leaks.	mo
Operate safety valves.	mo
Check and replace intake filter (more often if necessary).	mo
Check belt tension.	mo
Inspect valve assemblies.	6 mos
Check P/E switch setting.	yr
Inspect all electrical contacts.	yr
Check amp draw on motors.	yr
Check pump-up times.	yr
Change oil.	yr/2K hrs
Air Dryers	
Check air dryers for proper air drying. Change filter media if required. Repair or replace dryer if necessary.	week
Filters	
If filters are supplied on regulators, drain out condensation. If filters are not operating properly, repair or replace as needed.	mo
Pressure Regulator	
Check air pressure regulators for proper operation. Adjust, repair, or replace if necessary.	mo

Table 17-2. Pneumatic control system instrumentation and electrical

Pneumatic Control System Instrumentation & Electrical	
Action	***Frequency***
Transmitters and Controllers	
Calibrate and adjust in accordance with the manufacturer's recommendations.	mo
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controlled temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

CHAPTER 18

SANITARY WASTE SYSTEMS

18-1. Minimum maintenance activities for sanitary waste systems

The tables that follow indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment.

18-2. General maintenance procedures for sanitary waste systems

Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 18-1 provides maintenance information for drain and vent systems. Table 18-2 provides maintenance information for packaged treatment equipment. Table 18-3 provides maintenance information for sewage lift stations and sewage sump units. Table 18-4 provides maintenance information for sanitary waste system instrumentation and electrical.

18-3. Effluent quality

Periodic fine-tuning of the wastewater treatment process is necessary to maintain effluent quality at the desired level. Table 18-5 summarizes the various adjustments that may be made based upon a visual inspection of the wastewater at selected points within the treatment process.

Table 18-1. Drain and vent system

Drain and Vent System	
Action	***Frequency***
General	
Clean and inspect all of the piping, valves, and components associated with the drain and vent system and report all discrepancies to supervisor. Inspect for the following:	
Leaking piping or fixture connections (seals, packing, etc.)	mo
Corrosion.	mo
Sagging or misaligned piping.	mo
Exercise all valves and perform routine maintenance as follows:	
Inspect packing gland and tighten as necessary. Verify correct position and operation.	mo
Check for leaking seals.	mo
Vents	
Check vent terminals and verify that no blockages exist. Flush with water.	yr
Waste Piping	
Clean all building drain and sewer piping with hand or power rodding equipment	6 mos
Floor Drains	
Visually inspect floor drain.	6 mos
Remove grate. Flush drain with water to ensure drain flows free.	6 mos
Manholes	
WARNING! SANITARY MANHOLES MAY CONTAIN HARMFUL GASES. PROVIDE ADEQUATE VENTILATION TO THIS SPACE PRIOR TO ENTRY.	
Remove manhole cover and visually inspect interior.	3 mos
Remove all debris and sediment and flush with water.	3 mos

Table 18-2. Packaged treatment equipment

Packaged Treatment Equipment	
Action	***Frequency***
General	
Clean all areas where sediment accumulates.	day
Adjust treatment equipment per manufacturers' recommendations to give the desired effluent quality. If manufacturer's data is not available, use Table 18-5 as a guide.	per mfg
Aeration System	
Balance diffuser air flow.	day
Inspect air valves for leaks.	mo
Inspect and lubricate blower.	mo
Inspect blower drive and belts for wear and tension.	week
Clean air filter.	mo
Sludge System	
Check sludge return rate.	day
Scrape hopper.	day
Effluent System	
Clean and check effluent weir.	day
Sample effluent for odor and clarity.	day

Table 18-3. Sewage lift station and sewage sump unit

Sewage Lift Station and Sewage Sump Unit	
Action	***Frequency***
Sewage Pumps	
Wash down pumps with a pressure hose to remove sludge buildup on the pump body.	6 mos
Remove the pumps from the sump or wet pit, and do the following:	
On submersible pumps, check and/or replace the following:	
Seal oil.	yr
Motor housing.	yr
Lower mechanical seal.	yr
Oil or air chamber.	yr
Upper mechanical seal.	yr
Bearing lid and lower bearing.	yr
Cable.	yr
Stator.	yr
Impeller.	yr
Volute.	yr
Bottom plate.	yr
Seal probe.	yr
Perform megohm resistance test between pump body and power leads. Resistance should be in the megohm.	yr
On vertical units, check and/or replace the following:	
Impeller.	yr
Volute.	yr
Bottom bearing,	yr
Intermediate bearings.	yr
Grease seal.	yr
Packing.	yr
Shaft	yr
Lubricate bearings.	yr
Reinstall pumps into wetwell or sump, and check direction of pump rotation.	yr

Table 18-3. Sewage lift station and sewage sump unit (continued)

Sewage Lift Station and Sewage Sump Unit	
Action	***Frequency***
Check function of check valves (pump turns backwards or pump shuts off when check valves are bad).	yr
Check amps while pump is running and fully submerged. Compare with nameplate or technical data and check setting of overloads in control panel.	6 mos
Wet Pit or Sump	
WARNING! WET PITS AND SUMPS MAY CONTAIN HARMFUL GASES. PROVIDE ADEQUATE VENTILATION TO THESE SPACES PRIOR TO ENTRY.	
Remove any buildup of sediment and sludge in the bottom of the wet pit or sump.	3 mos
Controls	
Check the float switches for sludge buildup. Lift the switches from the pit and clean. After cleaning, visually inspect and allow to operate in sequence for proper pump operation.	3 mos
Check control panel for functioning check for moisture or corrosion.	3 mos

Table 18-4. Sanitary waste system instrumentation and electrical

Sanitary Waste System Instrumentation & Electrical	
Action	***Frequency***
Level Gauges	
Check for accuracy. Remove manhole cover and check gauge reading against calibrated dipstick. Recalibrate as required following equipment manufacturer's instructions.	yr
Pressure Gauges	
Isolate gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
Transmitters and Controllers	
Calibrate and adjust in accordance with the manufacturer's recommendations.	yr
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical Devices	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

Table 18-5. Effluent quality

Influent Color	Aeration Tank Color	Settling Tank Color	Color of Return Sludge	Odor	Condition	Adjustment
Gray	Chocolate brown	Clear	Chocolate brown	Earthy	Good operation	None
Gray	Chocolate brown	Clear	Chocolate brown	Earthy	Excessive foaming	Install or operate spray system
Gray	Chocolate brown	Clear	Chocolate brown	Musty	Floating lumps of grease in settling tank	Skim settling tank frequently. Clean or install grease trap.
Gray	Chocolate brown	Clear	Chocolate brown	Musty	Layer of sludge visible near surface of settling tank.	Increase sludge return rate. Scrape hopper.
Gray	Chocolate brown	Murky	Light brown	Slightly musty	Solids in effluent.	Reduce sludge return rate.
Gray	Light brown	Light brown	Light brown	Slightly septic	Floating solids in settling compartment.	Scrape hopper. Skim settling tank.
Gray	Light brown	Light brown	----	None	No sludge return.	Backwash sludge return. Scrape hopper.
Gray	Light brown	Brown slime floating on surface	Light brown	Slightly septic	Plant underloaded	Reduce running time.
Gray	Light brown	Black	Black	Musty	Inadequate return of sludge.	Increase sludge return rate.
Gray	Light brown	Clear	Light brown	None	Uneven tank roll.	Adjust valves until roll (mixing) is uniform.
Gray	Gray	Murky	Gray	None	Insufficient solids in plant.	Increase aeration. Increase sludge return rate.
Gray	Red	Reddish	Light brown	Septic	Over-aeration.	Reduce aeration.
Gray	Black	Black	Black	Septic	Insufficient aeration.	Increase aeration.
Gray	Black	Black	----	Septic	No air rising in tank. Blower not running.	Press reset on starter. Check V-belt. Check circuit breaker. Check power.
Black	Black	Black	Black	Septic	Septic wastewater.	Max aeration. Check influent for toxic material (bleach, gasoline, etc.

CHAPTER 19

GENERATORS

19-1. Minimum maintenance for generators

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 19-1 provides information on typical generator maintenance. Table 19-2 provides maintenance information for generators. Table 19-3 provides maintenance information for system controls.

19-2. General maintenance for generators

Preventive maintenance is a periodic checking and testing of equipment. The following discusses minimum preventive maintenance tasks as indicated in the tables. The frequency of the tasks is indicated in the tables.

a. Typical maintenance tasks. This section presents general instructions for maintaining generator systems.

(1) Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

(2) Review operator records concerning electrical load connected to the generators, and compare with equipment ratings. Operator records regarding generator lubrication and operating temperatures should also be reviewed, as well as any documented abnormal circumstances associated with generator or control system operation.

(3) Generator system equipment should be thoroughly inspected and all discrepancies reported to the shift supervisor.

(a) Inspect to ensure that warning signs exist. Replace as required.

(b) Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.

(c) Inspect air passages and remove any blockage.

(d) Inspect, investigate, and solve conditions for unusual odors.

(e) As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.

(f) Inspect electrical connections for degradation; repair as required.

(g) Inspect electrical insulation for discoloration and degradation; repair as required.

(h) Inspect, investigate, and solve conditions causing carbon tracks.

(i) Inspect equipment grounding components such as conductors and connections; repair as required.

(j) Inspect insulators for damage; replace as required.

(k) Inspect locking devices; repair as required.

(4) To clean equipment remove debris, dirt, and other foreign objects from all components, housings, cabinets, panels, etc.

(5) All electrical connections should be torqued to the proper design value.

(6) Verify operation of space heaters and control thermostat in generator or control panels. Check thermostat set point for proper setting.

(7) Verify the grounding of the equipment and associated neutral (system ground) if applicable.

(8) Conduct infrared test on all main current carrying equipment for hot spots that may indicate overload conditions or loose connections. Perform this test with the generator running.

b. Generators. Generator insulation testing and load testing are key elements of an effective maintenance program.

(1) Generator insulation tests shall be performed as described below.

(a) Perform insulation resistance tests using a megohmmeter in accordance with Institute of Electrical and Electronic Engineers (IEEE) 43, Recommended Practice for Testing Insulation Resistance of Rotating Machinery (2000) on the stator and rotor of both generator and exciter.

(b) Perform dielectric absorption testing using a megohmmeter.

(c) On generators operating at nominal 5 kV and above, a direct current (DC) overpotential test of the insulation should be performed.

(2) Standby generators should be load-tested every two weeks with a minimum of 50 percent load and for at least one (1) hour after the unit reaches a stable temperature. Prime power generators and standby generators should be load-tested after maintenance has been performed. The load tests shall record frequency and voltage output, and verify instrumentation for correct indications.

(3) Generator alignment and bearings shall be inspected as described below.

(a) Inspect bearings.

(b) Verify bearings are properly lubricated using lubricant recommended by the manufacturer.

(c) Perform vibration tests.

(d) Check alignment and couplings.

(e) Some generators have bearings electrically isolated from the pedestal. If applicable, verify isolation with an ohmmeter.

(4) Using a true rms ammeter, measure the neutral current while generator is operating with site load. If amperage is abnormal, investigate for load imbalances and harmonics.

c. Generator switchgear. For preventive maintenance of switchgear, refer to the applicable switchgear sections of either the primary electrical distribution or secondary electrical distribution chapters, chapter 20 and 21, respectively.

d. System controls. System controls shall be calibrated and exercised as described below.

(1) Using calibrated test instruments, calibrate ammeters, voltmeters, etc. Verify continuity of metering selector switch contacts with ohmmeter.

(2) Remove debris, dirt, and other foreign objects from all areas and components within the control panels.

(3) Programmable controllers, personal computers, microprocessors, etc., may be provided with diagnostic programs which should be run. Investigate and correct errors.

(4) Because of the complexity, number of, and variety of automatic sequences, it is not within the scope of this manual to describe specific tests. Simulation of control sequences should be all-inclusive to the extent that personnel are confident the control system will respond correctly should an actual similar event occur. An example of this simulation would be to simulate the loss of normal power to a site having standby generation. This loss of power should command the generators to start, etc.

(5) Actuate each alarm input for the correct response. Use corrective measures as required.

(6) For systems that have two or more generators operate the system for all modes with one generator off-line to simulate failure to start and parallel. Repeat for each generator in the system. Note: Ensure that remaining generators can carry the connected load prior to running tests.

Table 19-1. Typical generator maintenance

Typical Generator Maintenance	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review maintenance records.	2 wks
Review operator records.	2 wks
Inspect equipment for the following:	
Inspect to ensure that warning signs exist. Replace as required.	2 wks
Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.	2 wks
Inspect air passages and remove any blockage.	2 wks
Inspect, investigate, and solve conditions for unusual odors.	2 wks
As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.	2 wks
Inspect electrical connections for degradation. Repair as required.	2 wks
Inspect electrical insulation for discoloration and degradation. Repair as required.	2 wks
Inspect, investigate, and solve conditions causing carbon tracks.	2 wks
Inspect equipment grounding components such as conductors and connections. Repair as required.	2 wks
Inspect insulators for damage. Replace as required.	2 wks
Inspect locking devices. Repair as required.	2 wks
Clean equipment.	yr
Tighten electrical connections.	yr
Verify space heater operation.	yr
Verify equipment grounding.	yr
Perform infrared tests.	yr

Table 19-2. Generators

Generators	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Test generator insulation.	
Perform insulation resistance tests using a megohmmeter in accordance with IEEE 43 on the stator and rotor of both generator and exciter.	yr
Perform dielectric absorption testing using a megohmmeter.	yr
On generators operating at nominal 5 kv and above, a DC overpotential test of the insulation should be performed.	yr
Load test generator.	
Load test standby generators with a minimum of 50 percent load for at least one (1) hour after the unit reaches a stable temperature.	2 wks
Load test prime power generators and standby generators after maintenance has been performed.	as req'd
Verify frequency and voltage output.	2 wks/as req'd
Verify instrumentation for correct indications.	2 wks/as req'd
Check alignment and bearings	
Inspect bearings.	yr
Verify bearings are properly lubricated using lubricant recommended by the manufacturer.	yr
Perform vibration tests.	yr
Check alignment and couplings.	yr
Some generators have bearings electrically isolated from the pedestal. If applicable, verify isolation with an ohmmeter.	yr
Measure and record neutral current.	yr

Table 19-3. System controls

Svstem Controls	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Calibrate control system metering.	
Using calibrated test instruments, calibrate ammeters, voltmeters, etc.	yr
Verify continuity of metering selector switch contacts with ohmmeter.	yr
Clean control panel.	yr
Run controller diagnostics.	6 mos
Simulate automatic control.	6 mos
Verify alarms.	yr
Simulate parallel generator failure.	yr

CHAPTER 20

PRIMARY ELECTRICAL DISTRIBUTION

20-1. Minimum maintenance activities for primary electrical distribution systems

For the purpose of this manual the primary electrical distribution system comprises all components operating above 600 volts. The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 20-1 provides maintenance information for typical primary distribution systems. Table 20-2 provides maintenance information for overhead pole line distribution systems. Table 20-3 provides maintenance information for medium voltage switchgear. Table 20-4 provides maintenance information for primary distribution feeders. Table 20-5 provides maintenance information for transformers. Table 20-6 provides maintenance information for primary distribution system protection.

20-2. Maintenance schedule

Maintenance will take place ordinarily during scheduled shutdowns. However, other conditions that force the issue or provide an opportunity are emergency shutdowns, acts of nature, fault occurrences, associated shutdowns, and abnormal operating conditions. Typical maintenance tasks should be performed on all electrical equipment as applicable. Inspection frequencies may be increased as required based on observations and experience.

a. Typical maintenance tasks. This section presents general instructions for maintaining primary electrical distribution systems.

(1) Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

(2) Review operator records concerning electrical load readings, and compare with equipment ratings. Operator records regarding operating temperatures and any documented abnormal circumstances associated with the system should also be reviewed.

(3) Primary electrical distribution equipment should be thoroughly inspected and all discrepancies reported to the shift supervisor.

(a) Inspect to ensure that warning signs exist. Replace as required.

(b) Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.

(c) Inspect air passages and remove any blockage.

(d) Inspect, investigate, and solve conditions for unusual odors.

(e) Inspect locking devices. Repair as required.

(f) As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.

(g) Inspect electrical connections for degradation and tightness. Repair as required.

(h) Inspect electrical insulation for discoloration and degradation. Repair as required.

(i) Inspect, investigate, and solve conditions causing carbon tracks.

(j) Inspect equipment grounding components such as conductors and connections. Repair as required.

(k) Inspect insulators for damage. Replace as required.

(l) Inspect liquid immersed equipment for leaks and damage.

(m) Inspect indicating lights for correct illumination.

(4) Remove debris, dirt, and other foreign objects from all components, housings, cabinets, panels, etc.

(5) All electrical connections should be torqued to the proper design value.

(6) Verify operation of space heaters and control thermostat. Check thermostat set point for proper setting.

(7) Verify the grounding of the equipment and associated neutral where applicable.

(8) Conduct an infrared test on all main current carrying equipment for hot spots that may indicate overload conditions or loose connections.

(9) Using calibrated test instruments, calibrate ammeters, voltmeters, etc. Verify continuity of metering selector switch contacts with ohmmeter.

b. Overhead pole line distribution. Proper maintenance of the overhead pole line distribution system is essential to ensure the reliable delivery of electrical power to facility loads.

(1) Inspect overhead pole line distribution hardware for the following conditions.

(a) Inspect conductors for damage, proper connections, sag, and clearances.

(b) Inspect for leaning and damaged poles.

(c) Inspect earth conditions for washouts, etc., which may affect the foundation integrity of the supporting structure.

(d) Inspect cross arms for deterioration.

(e) Inspect structure anchoring guys.

(f) Inspect overhead pole line mounting hardware, including conductor support and support structure, for looseness.

(g) Inspect transformers, insulators, cutouts, and lightning arresters for damage and cleanliness.

(h) Inspect lightning arrester air gap if applicable.

(i) Inspect right-of-way for clearances to energized equipment from trees, brush, and other grounded objects.

(j) Inspect overhead ground wires and static lines for damage, ground connections, sag, and clearances.

(2) In most cases, cleaning of insulators is not necessary. But, in areas where contaminants such as salt, cement/lime, dust, bird defecation, chemicals, smog, cooling tower effluent, etc., may cause tracking on the insulator surface, cleaning cycles should be established, as the need to clean will vary depending on the severity of contamination.

(3) Test wood poles twenty years after installation and every five years thereafter. Excavate earth around the pole to a depth of 18 inches. Perform non-destructive evaluation of pole strength using sound waves. Prod the pole below ground line to determine the extent of external decay. Perform pole borings below ground line for internal defects. As an alternative to pole boring, an electrical resistance analysis using a shigometer® may be performed. The shigometer® generates a pulsed direct current (DC) electrical current and measures resistance of wood tissues which indicates the condition of the wood.

(4) Conduct radio interference test by monitoring radio frequency test equipment to search for loose connections, flashover, etc.

c. Medium voltage switchgear. A medium voltage switchgear assembly is comprised of switching, interrupting, control, metering, and protective devices housed in a metal enclosure together with associated conductors and electrical interconnections.

(1) Review operator records indicating the number of, and causes for, circuit breaker operation.

(2) Inspect medium voltage switchgear for the following conditions.

(a) Inspect, investigate, and solve conditions causing carbon tracks.

(b) Inspect barriers and shutters for physical damage. Prove shutter operation if possible.

(3) Test switchgear phase bus insulation as described below.

(a) Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.

(b) Perform dielectric absorption test on each phase using a megohmmeter.

(c) Perform DC over-potential test on each phase-to-phase and each phase-to-ground.

(d) Perform power factor test on each phase.

(4) Frequency of circuit breaker inspection should be based on the number of operations and the electrical load interrupted during those operations. The higher the number of operations under load, the more often the circuit breaker should be inspected.

(a) Inspect draw-out contacts for abnormal wear, tension, and discoloration. Correct as required.

(b) Inspect breaker current carrying components for discoloration that may indicate overheating. Replace as required.

(c) Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.

(d) Verify the opening and closing sequence of arcing, intermediate, and main contacts on air circuit breakers.

(e) Verify interlocks preventing a closed breaker from being withdrawn from or connected to the switchgear bus.

(f) Inspect and dress current carrying contacts on air circuit breakers in accordance with manufacturer's recommendations.

(g) Inspect the contact wear indicator on vacuum circuit breakers. Replace contact vacuum bottle as required.

(5) Circuit breakers shall be tested in accordance with the following.

(a) Perform test operations to prove correct actuation of breakers' trip and close components, including spring charging motors, trip solenoids, indicating targets, etc.

(b) Perform contact resistance test.

(c) Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.

(d) Perform DC over-potential test on each phase-to-phase and each phase-to-ground.

(e) Perform voltage test across each open contact of vacuum circuit breaker to verify vacuum condition of the vacuum bottle.

(f) Prove circuit breaker operation by actuation of each associated protective relay.

(g) Prove circuit breaker operation by actuation of each breaker manual control switch.

(6) Switchgear provided with alarms should have the alarms actuated by simulating the alarm condition if possible. If operation is not correct, repair and adjust as required.

(7) Test air switches as described below.

(a) Perform DC over-potential test on each pole-to-pole and each pole-to-ground.

(b) Perform contact resistance test across each switch and fuse holder.

d. Primary distribution feeders. Preventive maintenance of electrical cable and busway installations is critical to ensuring continuity of service to loads.

(1) Electrical cables shall be inspected for the following conditions.

(a) Accessible portions of cables, especially splices and terminations, should be visually inspected for insulation damage, tracking, discoloration, signs of corona, etc.

(b) Inspect cable shield grounding equipment such as conductors and connections. Repair as required.

(2) Cable insulation tests shall be performed as described below. Cable test should be done three years after installation and every five years thereafter.

(a) Test the cable shield continuity to ground with ohmmeter.

(b) Perform insulation resistance test with megohmmeter.

(c) Perform DC over-potential test on each cable in accordance with American National Standards Institute/Institute of Electrical and Electronic Engineers (ANSI/IEEE) 400, Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field.

(3) Busway insulation tests shall be performed as described below.

(a) Perform insulation resistance test, phase-to-phase and phase-to-ground.

(b) Perform DC over-potential test on each phase.

e. Transformers. Transformers may be either liquid filled or dry type. Each requires different maintenance techniques.

(1) Inspect solid electrical insulation for discoloration and degradation. Repair as required.

(2) For liquid filled transformers, insulating oil shall be tested as described below.

(a) Perform dielectric strength test in accordance with American Society for Testing and Materials (ASTM) D 877, Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes (1995).

(b) Perform acidity test in accordance with ASTM D 1534, Standard Test Method for Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration (1995).

(c) Perform color test in accordance with ASTM D 1524, Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field (1999).

(d) Should the above oil tests be close to established limits, then laboratory tests for pour point, flash point, viscosity, specific gravity, interfacial tension, free ions, power factor, water content, sulfur compound test, and others listed in ASTM D 117, Standard Guide for Sampling, Test Methods, Specifications, and Guide for Electrical Insulating Oils of Petroleum Origin (1996), may be performed to make a final determination of oil condition.

(3) Transformers utilizing forced cooling systems (fans, oil pumps, etc.) shall be tested as described below.

(a) Inspect forced cooling system equipment for damage, etc.

(b) Operate system by simulating high temperature at controlling devices.

(4) Actuate transformer protective relays such as rate-of-pressure increase relay. If operation is not correct, repair and adjust as required.

(5) Transformers with alarms like temperature, level, pressure, pressure relief device, etc., should have alarms actuated. If operation is not correct, repair and adjust as required.

f. Primary distribution protection. Proper maintenance and application of fuses, relays, and other protective devices ensures electrical equipment is adequately protected and allows selective de-energization of the power distribution system to maximize reliability.

(1) Inspect fuses as described below.

(a) Inspect fuse and fuse holder for physical damage. Replace as required.

(b) Inspect the sealing disk on expulsion type fuses. If defective, replace fuse.

(2) Inspect protective relays as described below.

(a) Inspect relays for signs of physical damage.

(b) Clean the relay of debris and dust.

(c) On disk relays, ensure the rotating disk has proper clearance.

(d) Inspect, investigate, and solve conditions causing the presence of moisture.

(e) On rotating disk relays, rotate the disk and verify proper contact closure. Adjust as required.

(f) Inspect condition of contacts. Replace as required.

(3) Using a calibrated test set, all protective relays should be calibrated.

(4) Inspect lightning arrester air gap if applicable. In most cases, cleaning of arresters installed outdoors is not necessary. But, in areas where contaminants such as salt, cement/lime, dust, bird defecation, chemicals, smog, cooling tower effluent, etc., may cause tracking on the insulator surface, cleaning cycles should be established as the need to clean will vary depending on the severity of contamination.

Table 20-1. Typical primary distribution maintenance

Typical Primary Distribution Maintenance	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review maintenance records.	2 wks
Review operator records.	2 wks
Inspect equipment for the following:	
Inspect to ensure that warning signs exist. Replace as required.	yr
Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.	yr
Inspect air passages and remove any blockage.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr
Inspect locking devices. Repair as required.	yr
As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.	yr
Inspect electrical connections for degradation and tightness. Repair as required.	yr
Inspect electrical insulation for discoloration and degradation. Repair as required.	yr
Inspect, investigate, and solve conditions causing carbon tracks.	yr
Inspect equipment grounding components such as conductors and connections. Repair as required.	yr
Inspect insulators for damage. Replace as required.	yr
Inspect liquid immersed equipment for leaks and damage.	yr
Inspect indicating lights for correct illumination.	yr
Clean equipment.	yr
Tighten electrical connections.	yr
Verify space heater operation.	yr
Verify equipment grounding.	yr
Perform infrared test.	yr
Calibrate recording and indicating metering.	yr

Table 20-2. Overhead pole line distribution

Overhead Pole Line Distribution	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Inspect overhead pole line distribution system for the following:	
Inspect conductors for damage, proper connections, sag, and clearances.	6 mos
Inspect for leaning and damaged poles.	6 mos
Inspect earth conditions for washouts, etc., which may affect the foundation integrity of the supporting structure.	6 mos
Inspect cross arms for deterioration.	6 mos
Inspect structure anchoring guys.	6 mos
Inspect overhead pole line mounting hardware, including conductor support and support structure, for looseness.	6 mos
Inspect transformers, insulators, cutouts, and lightning arresters for damage and cleanliness.	6 mos
Inspect lightning arrester air gap if applicable.	6 mos
Inspect right-of-way for clearances to energized equipment from trees, brush, and other grounded objects.	6 mos
Inspect overhead ground wires and static lines for damage, ground connections, sag, and clearances.	6 mos
Clean insulators.	6 mos
Test wood poles (20 years after installation, then every 5 years).	20 yrs/5 yrs
Perform radio interference test.	6 mos

Table 20-3. Switchgear

Switchgear	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES. SWITCHGEAR BUS INSULATION IS NOT DESIGNED TO PROTECT AGAINST ELECTRICAL SHOCK. CONTACT WITH THIS BUS OR ITS CONNECTIONS SHOULD BE AVOIDED WHEN SWITCHGEAR IS ENERGIZED.	
Review operator records.	yr
Inspect switchgear for the following:	
Inspect, investigate, and solve conditions causing carbon tracks.	yr
Inspect barriers and shutters for physical damage. Prove shutter operation if possible.	yr
Test switchgear phase bus insulation.	
Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.	yr
Perform dielectric absorption test on each phase using a megohmmeter.	yr
Perform DC over-potential test on each phase-to-phase and each phase-to-ground.	yr
Perform power factor test on each phase.	yr
Service circuit breakers.	
Inspect draw-out contacts for abnormal wear, tension, and discoloration. Correct as required.	yr
Inspect breaker current carrying components for discoloration that may indicate overheating. Replace as required.	yr
Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.	yr
Verify the opening and closing sequence of arcing, intermediate, and main contacts on air circuit breakers.	yr
Verify interlocks preventing a closed breaker from being withdrawn from or connected to the switchgear bus.	yr
Inspect and dress current carrying contacts on air circuit breakers in accordance with manufacturer’s recommendations.	yr
Inspect the contact wear indicator on vacuum circuit breakers. Replace contact vacuum bottle as required.	yr
Test circuit breakers.	

Table 20-3. Switchgear (continued)

Switchgear	
Action	***Frequency***
Perform test operations to prove correct actuation of breakers' trip and close components, including spring charging motors, trip solenoids, indicating targets, etc.	yr
Perform contact resistance test.	yr
Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.	yr
Perform DC over-potential test on each phase-to-phase and each phase-to-ground.	yr
Perform voltage test across each open contact of vacuum circuit breaker to verify vacuum condition of the vacuum bottle.	yr
Prove circuit breaker operation by actuation of each associated protective relay.	yr
Prove circuit breaker operation by actuation of each breaker manual control switch.	yr
Verify switchgear alarms.	yr
Test air switch.	
Perform DC over-potential test on each pole-to-pole and each pole-to-ground.	yr
Perform contact resistance test across each switch and fuse holder.	yr

Table 20-4. Primary distribution feeders

Primary Distribution Feeders	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES. HIGH VOLTAGE TESTING OF CABLE MAY CAUSE INSULATION FAILURE. ALTERNATE POWER SOURCE TO SERVE THE LOAD SHOULD BE PLANNED FOR PRIOR TO TESTING.	
Inspect cable installations for the following:	
Accessible portions of cables, especially splices and terminations, should be visually inspected for insulation damage, tracking, discoloration, signs of corona, etc.	yr
Inspect cable shield grounding equipment such as conductors and connections. Repair as required.	yr
Cable insulation test[1].	
Test the cable shield continuity to ground with ohmmeter.	3 yrs/5 yrs
Perform insulation resistance test with megohmmeter.	3 yrs/5 yrs
Perform DC over-potential test on each cable in accordance with ANSI/IEEE 400.	3 yrs/5 yrs
Busway insulation test	
Perform insulation resistance test, phase-to-phase and phase-to-ground.	5 yrs
Perform DC over-potential test on each phase.	5 yrs

[1]Three years after installation, then every five years.

Table 20-5. Transformers

Transformers	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Inspect solid electrical insulation for discoloration and degradation.	yr
Perform insulating oil test for liquid filled transformers	
Perform dielectric strength test in accordance with ASTM D 877.	yr
Perform acidity test in accordance with ASTM D 1534.	yr
Perform color test in accordance with ASTM D 1524.	yr
Verify forced cooling systems	
Inspect forced cooling system equipment for damage, etc.	yr
Operate system by simulating high temperature at controlling devices.	yr
Verify transformer relay protection	yr
Verify transformer alarms	yr

Table 20-6. Primary distribution protection

Primary Distribution Protection	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Inspect fuses for the following:	
Inspect fuse and fuse holder for physical damage. Replace as required	yr
Inspect the sealing disk on expulsion type fuses. If defective, replace fuse.	yr
Inspect protective relays for the following:	
Inspect relays for signs of physical damage.	yr
Clean the relay of debris and dust.	yr
On disk relays, ensure the rotating disk has proper clearance.	yr
Inspect, investigate, and solve conditions causing the presence of moisture.	yr
On rotating disk relays, rotate the disk and verify proper contact closure. Adjust as required.	yr
Inspect condition of contacts. Replace as required.	yr
Calibrate protective relays.	yr
Inspect lightning arrester air gap (if applicable).	yr
Clean arresters as required. Cleaning cycle will depend on environment in which arrester is installed.	as req'd

CHAPTER 21

SECONDARY ELECTRICAL DISTRIBUTION

21-1. Minimum maintenance activities for secondary electrical distribution systems

For the purpose of this manual the secondary electrical distribution system comprises all components operating at 600 volts and below. The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment subsystems, or components. Maintenance actions included in this chapter are for various modes of operation, subsystems, or components. Table 21-1 provides information on typical secondary distribution system maintenance. Table 21-2 provides maintenance information for low voltage switchgear, switchboards, and panelboards. Table 21-3 provides maintenance information for transformers. Table 21-4 provides maintenance information for motor control centers (MCC) and motor starters. Table 21-5 provides maintenance information for transfer switches. Table 21-6 provides maintenance information for safety switches. Table 21-7 provides maintenance information for secondary distribution feeders.

21-2. General maintenance procedures for secondary electrical distribution

Typical maintenance tasks should be performed on all electrical equipment as applicable. Inspection frequencies may be increased as required based on observations and experience.

a. Typical maintenance tasks. This section presents general instructions for maintaining secondary electrical distribution systems.

(1) Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

(2) Review operator records concerning electrical load readings; compare with equipment ratings. Operator records regarding operating temperatures and any documented abnormal circumstances associated with the system should also be reviewed.

(3) Secondary electrical distribution equipment should be thoroughly inspected and all discrepancies reported to the shift supervisor.

(a) Inspect to ensure that warning signs exist. Replace as required.

(b) Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.

(c) Inspect air passages and remove any blockage.

(d) Inspect, investigate, and solve conditions for unusual odors.

(e) As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.

(f) Inspect electrical connections for degradation and tightness. Repair as required.

(g) Inspect electrical insulation for discoloration and degradation. Repair as required.

(h) Inspect equipment grounding components such as conductors and connections. Repair as required.

(i) Inspect insulators for damage. Replace as required.

(j) Inspect liquid immersed equipment for leaks and damage.

(k) Inspect indicating lights for correct illumination.

(4) Remove debris, dirt, and other foreign objects from all components, housings, cabinets, panels, etc.

(5) All electrical connections should be torqued to the proper design value.

(6) Verify operation of space heaters and control thermostat. Check thermostat set point for proper setting.

(7) Verify the grounding of the equipment and associated neutral where applicable.

(8) Conduct infrared test on all main current carrying equipment for hot spots that may indicate overload conditions or loose connections.

(9) Using calibrated test instruments, calibrate ammeters, voltmeters, etc. Verify continuity of metering selector switch contacts with ohmmeter.

b. Low voltage switchgear, switchboards, and panelboards. A preventive maintenance plan for low voltage power distribution equipment such as switchgear, switchboards, and panelboards shall include the following activities.

(1) Review operator records indicating the number of and causes for breaker operations.

(2) Inspect barriers and shutters for physical damage. Prove switchgear shutter operation if possible.

(3) Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.

(4) Frequency of circuit breaker inspection should be based on the number of operations and the electrical load interrupted during those operations. The higher the number of operations under load, the more often the circuit breaker should be inspected.

(a) Inspect drawout contacts for abnormal wear, tension, and discoloration. Correct as required.

(b) Inspect breakers' current carrying components for discoloration that may indicate overheating. Replace as required.

(c) Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.

(d) Verify interlocks preventing a closed switchgear drawout breaker from being withdrawn-from or connected-to the switchgear bus.

(e) Inspect and dress current carrying contacts on air circuit breakers in accordance with manufacturer's recommendations.

(5) Power circuit breakers shall be tested in accordance with the following.

(a) Perform test operations to prove correct actuation of breakers' trip and close components, including spring charging motors, trip solenoids, indicating targets, etc.

(b) Perform contact resistance test.

(c) Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.

(d) Prove circuit breaker operation by actuation of each associated protective device.

(e) Prove circuit breaker operation by actuation of each breaker's manual control switch or handle.

(6) Molded-case circuit breakers shall be tested in accordance with the following.

(a) Perform overcurrent test on critical load breakers to prove correct actuation of breaker's trip and close components.

(b) Perform contact resistance test on critical load breakers.

(c) Prove circuit breaker operation by actuation of each breaker manual control switch or handle.

(7) Equipment provided with alarms should have the alarms actuated by simulating the alarm condition if possible. If operation is not correct, repair and adjust as required.

(8) Using a calibrated test set, all relay and solid-state type protective devices should be calibrated.

(9) With more electrical load equipment using solid state devices containing harmonic producing components like semiconductor controlled rectifiers (SCR), a harmonic analysis should be performed if such non-linear load equipment is connected to the secondary electrical distribution system. This analysis may first be performed with an oscilloscope to determine the extent of harmonics. Should further evaluation be required, a harmonic distortion analyzer should be utilized.

(10) Neutral currents should be measured with a true rms meter to determine load imbalances and identify harmonic currents. A record of the measurements should be maintained for future comparison.

c. Transformers. Low voltage transformers are generally of dry type construction.

(1) Inspect solid electrical insulation for discoloration and degradation.

(2) Transformers utilizing forced cooling systems shall be tested as described below.

(a) Inspect forced cooling system equipment for damage, etc.

(b) Operate system and if possible, by simulating high temperature at controlling devices.

(3) Transformers with temperature, level, pressure, pressure relief device, etc., alarms should have alarms actuated. If operation is not correct, repair and adjust as required.

d. Low-voltage power filters. See chapter 27 for inspection and testing of power filters.

e. MCCs and motor starters. There are many varieties of MCCs and motor starters. The maintenance recommendations that follow can be applied to most product types likely to be encountered.

(1) Inspect MCCs and starters as described below.

(a) Inspect main contacts and auxiliary contacts on contactors.

(b) Inspect pushbuttons, indicating lights, selector switches, etc. for damage. Replace as required.

(c) Inspect indicating lamps for burned out bulbs or improper illumination. Repair as required.

(2) Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.

(3) Frequency of MCC unit inspection should be based on the number of operations and the electrical load during those operations. The higher the number of operations under load, the more often the unit should be inspected.

(a) Inspect drawout contacts for abnormal wear, tension, and discoloration. Correct as required.

(b) Inspect units' current carrying components for discoloration that may indicate overheating. Replace as required.

(c) Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.

(d) Verify mechanical interlocks.

(e) Inspect and dress current carrying contacts on switches and contactors in accordance with

manufacturer's recommendations.

(4) Motor starters shall be tested as described below.

(a) Manually operate switches and circuit breakers to verify correct operation.

(b) Operate starter unit using all manual and automatic control devices to ensure correct operation.

(c) Verify correct interlocking action with other associated equipment.

(d) Verify correct indicating light operation.

(5) Equipment provided with alarms should have the alarms actuated by simulating the alarm condition if possible. If operation is not correct, repair and adjust as required.

f. Automatic transfer switches. Proper maintenance of automatic transfer switches ensures emergency power will be available to mission critical loads when needed.

(1) Review operator records indicating the number of transfer operations.

(2) Frequency of transfer switch inspection should be based on the number of operations and the electrical load during those operations. The higher the number of operations under load, the more often the circuit breaker should be inspected.

(a) Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.

(b) Verify operation of mechanical interlocks.

(c) Inspect and dress current carrying contacts in accordance with manufacturer's recommendations.

(3) Automatic transfer switches shall be tested as described below.

(a) Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.

(b) Perform contact resistance test.

(c) Prove correct operation of the transfer switches by manually initiating transfers in both directions.

(d) Simulate the automatic conditions requiring automatic transfer switches to transfer in both directions. Verify correct operation.

(e) Verify starting of generators where applicable.

(f) Verify correct indicating light operation.

(4) Equipment provided with alarms should have the alarms actuated and if possible, by simulating the alarm condition. If operation is not correct, repair and adjust as required.

g. Safety switches. Safety switches are commonly used as a lockout device to de-energize equipment for maintenance activities. As such, their proper operation is vital to providing a safe working environment for maintenance personnel.

(1) Safety switches shall be inspected as described below.

(a) Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.

(b) Verify operation of mechanical interlocks.

(c) Inspect and dress current carrying contacts in accordance with manufacturer's recommendations.

(2) Safety switches shall be tested as described below.

(a) Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter of each critical load switch.

(b) Perform contact resistance test on each critical load switch.

h. Secondary distribution feeders. Preventive maintenance of low-voltage electrical cable and busway installations is critical to ensuring continuity of service to loads.

(1) Accessible portions of cables, especially splices and terminations, should be visually inspected for insulation damage, discoloration, etc.

(2) Perform insulation resistance test with megohmmeter.

(3) Perform busway insulation resistance test, phase-to-phase and phase-to-ground.

i. Onsite generators. See chapter 19 for preventive maintenance information concerning generators.

Table 21-1. Typical secondary distribution maintenance

Typical Secondary Distribution Maintenance	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review maintenance records.	2 wks
Review operator records.	2 wks
Inspect equipment for the following:	
Inspect to ensure that warning signs exist. Replace as required.	yr
Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.	yr
Inspect air passages and remove any blockage.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr
As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.	yr
Inspect electrical connections for degradation and tightness. Repair as required.	yr
Inspect electrical insulation for discoloration and degradation. Repair as required.	yr
Inspect equipment grounding components such as conductors and connections. Repair as required.	yr
Inspect insulators for damage. Replace as required.	yr
Inspect liquid immersed equipment for leaks and damage.	yr
Inspect indicating lights for correct illumination.	yr
Clean equipment.	yr
Tighten electrical connections.	yr
Verify space heater operation.	yr
Verify equipment grounding.	yr
Perform infrared test.	yr
Calibrate recording and indicating metering.	yr

Table 21-2. Low voltage switchgear, switchboards, and panelboards

Low Voltage Switchgear, Switchboards, and Panelboards	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO NSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES. SWITCHGEAR BUS INSULATION IS NOT DESIGNED TO PROTECT AGAINST ELECTRICAL SHOCK. CONTACT WITH THIS BUS OR ITS CONNECTIONS SHOULD BE AVOIDED WHEN SWITCHGEAR IS ENERGIZED.	
Review operator records.	yr
Inspect barriers and shutters for physical damage.	yr
Test phase bus insulation.	yr
Service circuit breakers.	yr
Inspect drawout contacts for abnormal wear, tension, and discoloration. Correct as required.	yr
Inspect breakers' current carrying components for discoloration that may indicate overheating. Replace as required.	yr
Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.	yr
Verify interlocks preventing a closed switchgear drawout breaker from being withdrawn from or connected to the switchgear bus.	yr
Inspect and dress current carrying contacts on air circuit breakers in accordance with manufacturer's recommendations.	yr
Test power circuit breakers.	
Perform test operations to prove correct actuation of breakers' trip and close components, including spring charging motors, trip solenoids, indicating targets, etc.	yr
Perform contact resistance test.	yr
Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.	yr
Prove circuit breaker operation by actuation of each associated protective device.	yr
Prove circuit breaker operation by actuation of each breaker's manual control switch or handle.	yr
Test molded-case circuit breakers.	
Perform overcurrent test on critical load breakers to prove correct actuation of breaker's trip and close components.	yr

Table 21-2. Low voltage switchgear, switchboards, and panelboards (continued)

Low Voltage Switchgear, Switchboards, and Panelboards	
Action	***Frequency***
Perform contact resistance test on critical load breakers.	yr
Prove circuit breaker operation by actuation of each breaker manual control switch or handle.	yr
Verify equipment alarms	yr
Protective device calibration	yr
Perform harmonics analysis	yr
Measure and record neutral currents	yr

Table 21-3. Secondary system transformers

Transformers	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Inspect solid electrical insulation for discoloration and degradation.	6 mos
Verify forced cooling systems	
Inspect forced cooling system equipment for damage, etc.	yr
Operate system by simulating high temperature at controlling devices.	yr
Verify transformer alarms	yr

Table 21-4. MCCs and motor starters

MCCs and Motor Starters	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Inspect MCCs and motor starters for the following:	
Inspect main contacts and auxiliary contacts on contactors.	yr
Inspect pushbuttons, indicating lights, selector switches, etc.	yr
Inspect indicating lamps for burned out bulbs or improper illumination. Repair as required.	yr
Test phase bus insulation	yr
Service MCC units	
Inspect drawout contacts for abnormal wear, tension, and discoloration. Correct as required.	yr
Inspect units' current carrying components for discoloration that may indicate overheating.	yr
Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.	yr
Verify mechanical interlocks.	yr
Inspect and dress current carrying contacts on switches and contactors in accordance with manufacturer's recommendations.	yr
Test motor starter unit	
Manually operate switches and circuit breakers to verify correct operation.	yr
Operate starter unit using all manual and automatic control devices to ensure correct operation.	yr
Verify correct interlocking action with other associated equipment.	yr
Verify correct indicating light operation.	yr
Verify equipment alarms	yr

Table 21-5. Automatic transfer switches

Automatic Transfer Switches	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review operator records	yr
Inspect automatic transfer switches for the following:	
Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.	yr
Verify operation of mechanical interlocks.	yr
Inspect and dress current carrying contacts in accordance with manufacturer's recommendations.	yr
Test automatic transfer switches	
Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.	yr
Perform contact resistance test.	yr
Prove correct operation of the transfer switches by manually initiating transfers in both directions.	yr
Simulate the automatic conditions requiring automatic transfer switches to transfer in both directions. Verify correct operations.	yr
Verify starting generators where applicable.	yr
Verify correct indicating light operation.	yr
Verify equipment alarms	yr

Table 21-6. Safety switches

Safety Switches	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Inspect safety switches for the following:	
Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.	yr
Verify operation of mechanical interlocks.	yr
Inspect and dress current carrying contacts in accordance with manufacturer's recommendations.	yr
Test safety switches	
Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter of each critical load switch.	yr
Perform contact resistance test on each critical load switch.	yr

Table 21-7. Secondary distribution feeders

Secondary Distribution Feeders	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Perform cable inspection	yr
Perform cable insulation test	3 yrs
Perform busway insulation test	5 yrs

CHAPTER 22

STATIC UNINTERRUPTIBLE POWER SUPPLY

22-1. Minimum maintenance activities for static uninterruptible power supply

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter for various modes of operation, subsystems, or components are summarized in table 22-1.

22-2. General maintenance procedures for static uninterruptible power supplies

Inspection frequencies may be increased as required based on observation and experience.

a. Review maintenance records. Review past maintenance records to find repair patterns indicating certain components to inspect during performance of preventive maintenance.

b. Review operator records. Review operator records concerning electrical load connected to the uninterruptible power supply (UPS) and compare with equipment ratings. Review operator records concerning number of transfers and their causes.

c. Inspect UPS module. Perform a general inspection of the UPS equipment as described below.

(1) Inspect to ensure that warning signs exist.

(2) Inspect equipment enclosures for damage, unauthorized openings, and corrosion of metallic objects.

(3) Inspect equipment grounding components such as conductors and connections.

(4) Inspect electrical connections for degradation.

(5) Inspect insulation for discoloration and degradation.

(6) Inspect equipment's internal air passages and remove any blockage.

(7) Inspect, investigate, and solve conditions for unusual odors.

(8) Inspect, investigate, and solve conditions for unusual noises.

(9) Inspect locking devices.

d. Inspect battery. UPS battery systems shall be inspected as described below.

(1) Perform visual checks of the following.

(a) Jar seals

(b) Terminal condition

(c) Battery plate discoloration - Discoloration can indicate battery problems.

(d) Sediment - Sedimentation is not a problem unless it reaches the plates in the cell and creates a short circuit. Rapid buildup indicates a problem cell or incorrect operation. Plates normally wear out before the sediment space is filled.

(e) Mossing - Mossing is the buildup of sulfates on battery plate surfaces. Excessive mossing can interfere with charging and discharging. Rapid buildup of moss indicates a problem cell.

(f) Gassing - Bubbles will form in the electrolyte of cells being charged. If bubbles do not form the cell has serious problems.

(g) Electrolyte level

(h) Vents

(i) Flame arresters

(2) Inspect batteries for leaks.

(3) Inspect battery rack for corrosion.

(4) Inspect battery rack for loose components.

(5) Verify that battery rack is grounded.

(6) Record battery bank charge voltage and the type of charge, be it float or equalization.

(7) Record battery charging current. Compare readings to previous readings.

(8) Measure specific gravity of electrolyte in pilot cell and correct for temperature.

(9) Inspect battery charger for abnormalities.

e. Inspect UPS ventilation filters. Clean or replace air filters as required.

f. Tighten electrical connections. Tighten each electrical connection, including battery intercell connectors, to the proper torque value.

g. Clean equipment. Thoroughly clean all components and areas of the UPS modules and batteries.

h. Calibrate metering. Using calibrated test equipment, calibrate all meters.

i. Test switches. Using a volt-ohmmeter, verify correct operation of all switches.

j. Test control cabinet. Test indicating lamps and replace as required. Test annunciator's local visual and audible alarm.

k. Perform battery cell tests. Battery cell testing shall be performed as described below.

(1) Measure specific gravity of each cell's electrolyte and correct for temperature. Compare with past readings.

(2) Record the voltage of each cell. Evaluate and compare with past readings.

(3) Record a sampling of intercell connector resistances. Resistance should typically be very low, on the order of 0.01 ohm.

l. Test phase bus insulation. Perform insulation resistance test on each phase-to-phase and phase-to-ground using a megohmmeter.

m. Perform infrared test. Test all main current carrying conductors for hot spots indicating overload or loose connections. This test should be simultaneous with the load test.

n. Perform harmonic analysis. An analysis to determine the presence of harmonics should be performed. This analysis may first be performed with an oscilloscope to determine the extent of harmonics. Should further evaluation be required, a harmonic distortion analyzer should be utilized.

o. Run diagnostics. If system is so equipped, run the internal system diagnostics to identify items needing correcting.

p. Verify alarm set points and control limits. Correct operation of alarms and controls shall be verified as described below.

(1) Calibrate alarm set points such as temperature alarms, overvoltage alarms, overcurrent alarms, etc.

(2) Calibrate control limits for static switch operation, cooling fan operation, cooling water control, oscillator, load sharing controls, etc.

(3) Verify correct action of any associated remote alarm.

q. Perform load test. This test may be eliminated if during the past six months the UPS operated on battery and successfully discharged close to the minimum battery voltage. Performing the above test in this case would shorten the life of the battery and would offset any gain from the test.

(1) A complete load test in accordance with Institute of Electrical and Electronic Engineers (IEEE) 450, Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Application, will prove the battery system. This procedure should include opening the UPS input (normal power) circuit breaker and supplying actual load from the batteries. Battery bank voltage and discharge times should be recorded. Testing should stop when either the maximum operational design time is reached or when the battery voltage reaches the designed minimum.

(2) As an alternate load test, the building load should be placed on maintenance bypass and load banks connected to the UPS. The load banks may be unity power factor or simulate design load including

power factor. The batteries would then supply the test load. Testing should be stopped when the battery voltage reaches the designed minimum.

r. Measure and record neutral currents. Using a true rms ammeter, measure neutral currents with site load. If amperage is abnormal, investigate for load imbalances and harmonics.

Table 22-1. Static uninterruptible power supply

Static Uninterruptible Power Supply	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review maintenance records.	mo
Review operators records.	mo
Inspect UPS module for the following:	
Inspect equipment enclosures for damage, unauthorized openings, and corrosion of metallic objects.	yr
Inspect equipment grounding components such as conductors and connections.	yr
Inspect electrical connections for degradation.	yr
Inspect insulation for discoloration and degradation.	yr
Inspect equipment's internal air passages and remove any blockage.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr
Inspect, investigate, and solve conditions for unusual noises.	yr
Inspect locking devices.	yr
Inspect UPS battery systems for the following:	
Perform visual checks of the following on batteries:	
Jar seals.	mo
Terminal condition.	mo
Battery plate discoloration.	mo
Sediment.	mo
Mossing.	mo
Gassing.	mo
Electrolyte level.	mo
Vents.	mo
Flame arresters.	mo
Inspect batteries for leaks.	mo
Inspect battery rack for corrosion.	mo

Table 22-1. Static uninterruptible power supply (continued)

Static Uninterruptible Power Supply	
Action	***Frequency***
Inspect battery rack for loose components.	mo
Verify that battery rack is grounded.	mo
Record battery bank charge voltage and the type of charge.	mo
Record battery charging current. Compare readings to previous readings.	mo
Measure specific gravity of electrolyte in pilot cell and correct for temperature.	mo
Inspect battery charger for abnormalities.	mo
Inspect UPS ventilation filters (Most UPS modules have air filters as part of the internal forced air cooling fans. The need to change or clean them will vary with the existing environmental conditions.)	mo
Tighten electrical connections	yr
Clean equipment	yr
Calibrate metering	mo
Using a volt-ohmmeter, verify correct operation of all switches.	mo
Test control cabinet	
Test indicating lamps and replace as required.	mo
Test annunciator's local visual and audible alarm.	mo
Perform battery cell tests	
Measure specific gravity of each cell's electrolyte and correct for correct temperature. Compare with past readings.	3 mos
Record the voltage of each cell. Evaluate and compare with past readings.	3 mos
Record a sampling of intercell connector resistances.	3 mos
Test phase bus insulation	yr
Perform infrared test	yr
Perform harmonic analysis	yr
Run diagnostics	mo
Verify alarm set points and control limits	
Calibrate alarm set points such as temperature alarms, overvoltage alarms, overcurrent alarms, etc.	yr
Calibrate control limits for static switch operation, cooling fan operation, cooling water control, oscillator, load sharing controls, etc.	yr

Table 22-1. Static uninterruptible power supply (continued)

Static Uninterruptible Power Supply	
Action	***Frequency***
Verify correct action of any associated remote alarm.	yr
Perform a complete load test in accordance with IEEE 450.	3 mos
Measure and record neutral currents	yr

CHAPTER 23

ROTARY UNINTERRUPTIBLE POWER SUPPLY

23-1. Minimum maintenance activities for rotary uninterruptible power supply

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment.

23-2. General maintenance procedures for rotary uninterruptible power supply

Maintenance tasks for rotary uninterruptible power supply (UPS) systems may involve many of the same activities as for static UPS systems. Additional maintenance not covered elsewhere in this manual is required for the induction coupler, synchronous machine and free wheeling coupler. Maintenance actions included in this chapter are summarized in table 23-1.

a. Insulation tests. Induction coupler and synchronous machine insulation shall be tested as described below.

(1) Perform insulation resistance tests using a megohmmeter in accordance with Institute of Electrical and Electronic Engineers (IEEE) 43, Recommended Practice for Testing Insulation Resistance of Rotating Machinery (2000) on the stator and rotor of the machine.

(2) Perform dielectric absorption testing using a megohmmeter.

b. Inspect bearings. The following tasks associated with bearings for induction coupler, synchronous machine and free-wheeling coupler should be performed.

(1) Inspect bearings.

(2) Verify bearings are properly lubricated with the correct lubricant per manufacturers' recommendation.

(3) Perform vibration tests.

(4) Check alignment.

c. Replace free wheeling coupler. Operating experience indicates the coupler on induction-coupled UPS systems should be replaced every 5 years.

d. Operate test mode. Applicable rotary UPS systems should be load tested weekly to ensure proper operation. Testing should be done with at least 50 percent electrical load and with sufficient time to bring all components to normal operating temperatures.

Table 23-1. Rotary uninterruptible power supply

Rotary Uninterruptible Power Supply	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Test induction coupler & synchronous machine insulation	
Perform insulation resistance tests using a megohmmeter in accordance with IEEE 43 on the stator and rotor of the machine.	yr
Perform dielectric absorption testing using a megohmmeter.	yr
Inspect bearings for induction coupler, synchronous machine, and free wheeling coupler.	
Verify bearings are properly lubricated with the correct lubricant per manufacturers' recommendation.	yr
Perform vibration tests.	yr
Check alignment.	yr
Replace free wheeling coupler	5 yrs
Perform load test	3 mos

CHAPTER 24

MOTOR GENERATORS

24-1. Minimum maintenance activities for motor generators

The table located at the end of this chapter indicates items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment.

24-2. General maintenance procedures for motor generators

This section covers the inspection and tests required for general maintenance. Maintenance actions included in this chapter are summarized in table 24-1.

a. Review maintenance records. Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

b. Review operator records. Review operator records concerning electrical load connected to the motor generators and compare with equipment ratings. Operator records regarding lubrication and operating temperatures should also be reviewed.

c. Equipment inspection. Perform a general inspection of the motor generator as described below.

(1) Inspect to ensure that warning signs exist. Replace as required.

(2) Inspect enclosure for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.

(3) Inspect air passages and remove any blockage.

(4) Inspect, investigate, and solve conditions for unusual odors.

(5) As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.

(6) Inspect electrical connections for degradation. Repair as required.

(7) Inspect electrical insulation for discoloration and degradation. Repair as required.

(8) Inspect equipment grounding components such as conductors and connections. Repair as required.

(9) Inspect locking devices. Repair as required.

d. Clean equipment. Remove debris, dirt, and other foreign deposits from all components and areas of the motor generator set.

e. Tighten electrical connections. All electrical connections should be torqued to the proper design value.

f. Insulation test. Test motor and generator insulation as described below.

(1) Perform insulation resistance tests using a megohmmeter in accordance with Institute of Electrical and Electronic Engineers (IEEE) 43, Recommended Practice of Testing Insulation Resistance of Rotating Machinery, on the stator and rotor of motor, generator, and exciter.

(2) Perform dielectric absorption testing using a megohmmeter.

g. Verify equipment grounding. Verify the grounding of the equipment and associated neutral if applicable.

h. Infrared test. Test all main current carrying equipment for hot spots that may indicate overload conditions or loose connections.

i. Load test generator. Standby motor generators should be load tested for at least 30 minutes after the unit reaches stable operating temperature. Load testing should be executed after any maintenance has been performed.

(1) Verify frequency and voltage output.

(2) Verify instrumentation for correct indications.

j. Inspect bearings. Motor generator set bearings require routine maintenance to ensure reliable operation.

(1) Inspect bearings.

(2) Verify bearings are properly lubricated per manufacturers' recommendation.

(3) Perform vibration tests.

(4) Check alignment and couplings.

k. Measure and record neutral current. Using a true rms ammeter, measure the neutral current while generator is operating with site load. If amperage is abnormal, investigate for load imbalances and harmonics.

l. Verify system controls. Motor generator controls shall be calibrated and tested as described below.

(1) Using calibrated test instruments, calibrate ammeters, voltmeters, etc.

(2) Verify continuity of metering selector switch contacts with ohmmeter.

(3) Run controller diagnostics if the motor generator set is provided with such.

(4) Simulate automatic and manual control sequences. Because of the complexity, number of, and variety of sequences, it is not within the scope of this manual to describe specific tests. Simulation of control sequences should be all-inclusive to the extent that personnel are confident the control system will respond correctly should an actual similar event occur.

(5) Verify alarms. Actuate each alarm input for the correct response. Use corrective measures as required.

Table 24-1. Motor generators

Motor Generators	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review maintenance records.	yr
Review operator records.	yr
Inspect motor generator sets for the following.	
Inspect to ensure that warning signs exist. Replace as required.	yr
Inspect enclosure for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.	yr
Inspect air passages and remove any blockage.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr
As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.	yr
Inspect electrical connections for degradation. Repair as required.	yr
Inspect electrical insulation of discoloration and degradation. Repair as required.	yr
Inspect equipment grounding components such as conductors and connections. Repair as required.	yr
Inspect locking devices. Repair as required.	yr
Clean equipment.	yr
Tighten electrical connections.	yr
Test motor and generator insulation.	
Perform insulation resistance tests using a megohmmeter in accordance with IEEE 43 on the stator and rotor of motor, generator, and exciter.	yr
Perform dielectric absorption testing using a megohmmeter.	yr
Verify equipment grounding.	yr
Perform infrared test.	yr
Load test generator.	
Verify frequency and voltage output.	yr[1]
Verify instrumentation for correct indications.	yr[1]

[1]Or after any maintenance work.

Table 24-1. Motor generators (continued)

Motor Generators	
Action	***Frequency***
Inspect bearings.	
Verify bearings are properly lubricated per manufacturers' recommendation.	yr
Perform vibration tests.	yr
Check alignment and couplings.	yr
Measure and record neutral current.	yr
Verify system controls.	
Using calibrated test instruments, calibrate ammeters, voltmeters, etc.	yr
Verify continuity of metering selector switch contacts with ohmmeter.	yr
Run controller diagnostics if the MG set is provided with such.	yr
Simulate automatic and manual control sequences.	yr
Verify alarms.	yr

CHAPTER 25

ELECTRICAL CONTROLS

25-1. Minimum maintenance activities for electrical control systems

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturers-recommended maintenance activities and procedures for specific pieces of equipment.

25-2. General maintenance procedures for electrical control systems

Maintenance actions included in this chapter are summarized in table 25-1. Additional maintenance tasks associated with specific electrical equipment are included in subsequent tables. Inspection frequencies may be increased as required based on observations and experience. Because of the sophisticated electronics utilized in electrical control systems, specially trained personnel may be required to perform certain preventive maintenance tasks. Factory representatives or service companies are available should in-house personnel not be comfortable with performing these tasks.

a. Typical electrical control system maintenance. Maintenance activities common to all control systems include the following.

(1) Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

(2) Review operator records looking for trouble entries.

(3) Perform a general inspection of control system components as described below.

(a) Inspect to ensure that voltage warning signs exist on equipment like power supplies.

(b) Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.

(c) Inspect air passages and remove any blockage.

(d) Inspect, investigate, and solve conditions for unusual odors.

(e) Inspect locking devices. Repair as required.

(f) As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.

(g) Inspect for loose wiring and components.

(h) Inspect electrical connections for degradation. Repair as required.

(i) Inspect electrical insulation for discoloration and degradation. Repair as required.

(j) Inspect equipment grounding components such as conductors and connections. Repair as required.

(k) Inspect indicating lights for correct illumination.

(4) Remove debris, dirt, and other foreign deposits from all components and areas of non-encapsulated equipment such as ventilated equipment, etc. Replace equipment ventilation filters as required.

(5) All electrical connections should be torqued to the proper design value.

(6) Control systems may have backup or redundant equipment such as power supplies or central processing units (CPUs). This equipment should be placed in service by simulating conditions one might expect to cause a transfer.

(7) Conduct Simulation of manual and automatic control sequences. Because of the complexity, number of, and variety of manual and automatic control sequences, it is not within the scope of this manual to describe specific tests. Simulation of control sequences should be all-inclusive to the extent that personnel are confident the control system will respond correctly should an actual similar event occur.

b. Manual control system. Verify continuity of selector switch, push buttons, and starter contacts. Repair or replace as recommended by the manufacturer.

c. Programmable Logic Controller (PLC) and Distributed Control System (DCS) maintenance. PLCs and DCSs have been designed with ease of maintenance in mind. Virtually all components are solid state, so maintenance is reduced to the replacement of modular, plug-in type components. Fault detection circuits and diagnostic indicators indicate if the component is working properly. Processors have self-diagnostics to indicate their operating status.

(1) Run operator initiated self-diagnostic programs as most units will be provided with some form of diagnostic software.

(2) Volatile memories may have battery backup to maintain programs during loss of normal power sources. Batteries should be tested to ensure memory will not be lost should normal power fail.

(3) Most electronic control equipment will have indicating lights that should be verified for proper status.

d. Relays. Electromechanical relays shall be inspected as described below.

(1) Conduct inspection of unit. Closely examine contacts for degradation. Repair or replace as required.

(2) Perform contact conductivity test. Verify continuity of critical starter and relay contacts. Repair or replace as recommended by manufacturer.

e. Control panels. Calibrate and test control panels as described below.

(1) Using calibrated test instruments, calibrate ammeters, voltmeters, etc. Verify continuity of metering selector switch contacts with ohmmeter.

(2) Actuate each alarm input for the correct response. Use corrective measures as required.

Table 25-1. Electrical control system

Electrical Control Svstem	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
General Maintenance	
Review maintenance records.	6 mos
Review operator records.	6 mos
Inspect electrical control systems for the following.	
Inspect to ensure that voltage warning signs exist on equipment like power supplies.	yr
Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.	yr
Inspect air passages and remove any blockage.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr
Inspect locking devices. Repair as required.	yr
As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.	yr
Inspect for loose wiring and components.	yr
Inspect electrical connections for degradation. Repair as required.	yr
Inspect electrical insulation for discoloration and degradation. Repair as required.	yr
Inspect equipment grounding components such as conductors and connections. Repair as required.	yr
Inspect indicating lights for correct illumination.	yr
Clean equipment.	yr
Tighten electrical connections.	yr
Verify operation of backup equipment.	6 mos
Simulate manual and automatic control sequences.	yr
Manual Control System	
Perform contact conductivity test.	yr
PLC/DCS Systems	
Run diagnostic programs.	6 mos

Table 25-1. Electrical control system (continued)

Electrical Control Svstem	
Action	***Frequency***
Test batteries.	6 mos
Verify indication lights.	6 mos
Relays	
Inspect contacts for degradation. Repair or replace as required.	yr
Perform contact conductivity tests.	yr
Control Panels	
Using calibrated test instruments, calibrate ammeters, voltmeters, etc.	yr
Verify continuity of metering selector switch contacts with ohmmeter.	yr
Verify alarms.	yr

CHAPTER 26

ELECTRONIC SECURITY SYSTEMS

26-1. Minimum maintenance activities for electronic security systems

The table located at the end of this chapter indicates items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are summarized in table 26-1.

26-2. General maintenance procedures for electronic security systems

Preventive maintenance is a periodic checking and testing of equipment. The following table indicates the minimum preventive maintenance tasks and the frequency of these tasks. Inspection frequencies may be increased as required based on observations and experience. Because of the sophisticated electronics utilized in electronic security systems (ESS), specially trained personnel may be required to perform certain preventive maintenance tasks. Factory representatives or service companies are available should in-house personnel not be comfortable with performing these tasks.

a. Review maintenance records. Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

b. Review operator records. Review operator records looking for trouble entries.

c. Equipment inspection. Perform a general inspection of the ESS as described below.

(1) Inspect to ensure that voltage warning signs exist on equipment like power supplies.

(2) Ensure that security system warning signs, if installed, are in their proper location.

(3) Intrusion detection system equipment may be labeled "security equipment not to be tampered with" to warn maintenance personnel. Make sure these labels are installed appropriately.

(4) Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.

(5) Inspect air passages and remove any blockage.

(6) Inspect, investigate, and solve conditions for unusual odors.

(7) Inspect locking devices. Repair as required.

(8) As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.

(9) Inspect equipment mounting for proper installation.

(10) Inspect for loose wiring and components.

(11) Inspect electrical connections for discoloration or corrosion. Repair as required.

(12) Inspect electrical insulation for discoloration and degradation. Repair as required.

(13) Inspect equipment grounding components such as conductors and connections. Repair as required.

d. Clean equipment. Remove debris, dirt, and other foreign deposits from all components and areas of non-encapsulated equipment such as ventilated control panels, etc.

e. Tighten electrical connections. All electrical connections should be torqued to the proper design value.

f. Perform detection operational tests. Operational tests are performed periodically to prove correct system operation but do not involve verification of equipment operating specifications such as the exact distance a protected door is opened before alarming. Verification of system or equipment specifications is conducted during performance testing.

(1) Open protected doors.

(2) Walk in protected rooms.

(3) Test metal detectors by passing metal through the detection area.

(4) Prove operation of fence disturbance sensors by shaking the fence.

(5) Walk in areas protected by invisible barrier detectors.

g. Perform detection performance tests. Performance tests vary from operational tests by verifying that equipment is in conformance with equipment or system specifications. These tests will usually require measuring devices or other calibrated instruments.

(1) Check for correct alarm activation when protected doors are opened a specified distance. Make adjustments as required.

(2) Test motion sensors by walking in strategic locations, with arms folded across chest to eliminate the Doppler effect of swinging arms, standing still, taking normal steps, crawling on the floor, etc. Adjust sensor sensitivity and orientation as required.

(3) Check performance of tamperproof switches.

h. Verify operation of backup equipment. Intrusion detection systems may have backup or redundant equipment such as power supplies or CPUs. This equipment should be placed in service by simulating conditions one might expect to cause a transfer.

Table 26-1. Electronic security

Electronic Securitv	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review maintenance records.	mo
Review operator records.	mo
Inspect electronic security equipment for the following.	
Inspect to ensure that voltage warning signs exist on equipment like power supplies.	yr
Ensure that security system warning signs, if installed, are in their proper location.	yr
ESS equipment may be labeled “security equipment not to be tampered with” to warn maintenance personnel. Make sure these labels are installed appropriately.	yr
Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.	yr
Inspect air passages and remove any blockage.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr
Inspect locking devices. Repair as required.	yr
As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.	yr
Inspect equipment mounting for proper installation.	yr
Inspect for loose wiring and components.	yr
Inspect electrical connections for discoloration or corrosion. Repair as required.	yr
Inspect electrical insulation for discoloration and degradation. Repair as required.	yr
Inspect equipment grounding components such as conductors and connections. Repair as required.	yr
Clean equipment.	yr
Tighten electrical connections.	yr
Perform detection operational tests.	
Open protected doors.	mo
Walk in protected rooms.	mo
Test metal detectors by passing metal through the detection area.	mo
Prove operation of fence disturbance sensors by shaking the fence.	mo

Table 26-1. Electronic security (continued)

Electronic Security	
Action	***Frequency***
Walk in areas protected by invisible barrier detectors.	mo
Perform detection performance tests	
Check for correct alarm activation when protected doors are opened a specific distance. Make adjustments as required.	6 mos
Test motion sensors by walking in strategic locations. Adjust sensor sensitivity and orientation as required.	6 mos
Check performance of tamperproof switches.	6 mos
Verify operation of backup equipment.	6 mos

CHAPTER 27

HIGH-ALTITUDE ELECTROMAGNETIC PULSE (HEMP) PROTECTION SYSTEMS

27-1. Minimum maintenance activities for HEMP protection systems

Preventive maintenance is a periodic checking and testing (surveillance) of equipment. In HEMP hardened facilities, this is commonly referred to as hardness maintenance (HM) and testing as hardened surveillance (HS). Maintenance actions included in this chapter are summarized in table 27-1.

a. HM testing. HM defines the requirements, approaches, and procedures for maintaining HEMP hardness elements, including the role of technical manuals, periodic inspections, repair activities, and repair verification.

b. HS testing. HS defines the techniques and procedures for conducting a HEMP hardness surveillance program, including grounds and bonds, shields, electrical filters, surge arresters, and other hardness elements. HS should include auditing past performance, testing current conditions, and analyzing test data.

27-2. Preventive maintenance

Because HEMP protective systems are passive, their effectiveness must be proven during hardness surveillance testing. Maintenance of HEMP protective systems is essential for the system to be effective. Technical manuals provided with HEMP protection system equipment should be consulted for specific procedures concerning maintenance, inspection repair or replacement, and testing. The following table indicates the minimum preventive maintenance tasks, including surveillance and the frequency of these tasks. Inspection frequencies may be increased as required based on observations and experience. Personnel should also review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

a. Doors. Inspect and test HEMP hardened doors in accordance with the following.

(1) Clean and inspect door and window finger stock to ensure integrity.

(2) Verify that doors fit snug and are plumb.

(3) Verify doors operate smoothly.

(4) Close all doors.

(5) Test doors using continuous wave radiated field method.

b. Honeycomb vents. Inspect and test honeycomb vents in accordance with the following.

(1) Clean dust and other foreign debris from vents.

(2) Inspect mounting seams and welds to ensure integrity.

(3) Test vents using continuous wave radiated field method.

c. Wave guide-below-cutoff devices. Inspect and test wave guide-below-cutoff devices in accordance with the following.

(1) Clean dust and other foreign debris from devices.

(2) Inspect mounting seams and welds to ensure integrity.

(3) Test devices using continuous wave radiated field method.

d. Gasketed seams. Inspect and test gasketed seams in accordance with the following.

(1) Inspect seams and gaskets for damage, openings, and corrosion. Repair and paint as required.

(2) Clean foreign debris from seams.

(3) Test gasketed seams using continuous wave radiated field method.

e. Bolted seams. Inspect and test bolted seams in accordance with the following.

(1) Inspect bolted seams for missing bolts, damage, openings, and corrosion. Repair and repaint as required.

(2) Clean foreign debris from seams.

(3) Test bolted seams with shielded enclosure leak detection method.

f. Welded seams. Inspect and test welded seams in accordance with the following.

(1) Inspect welded seams for damage, openings, and corrosion. Repair and repaint as required.

(2) Clean foreign debris from seams.

(3) Test welded seams with shielded enclosure leak detection method.

g. Threaded conduits. Inspect and test threaded conduits in accordance with the following.

(1) Inspect conduits for loose couplings, damage, openings, and corrosion. Repair and repaint as required.

(2) Clean foreign debris from couplings.

(3) Test threaded conduits with shielded enclosure leak detection method.

h. Welded conduits. Inspect and test welded conduits in accordance with the following.

(1) Inspect welded conduits for damage, openings, and corrosion. Repair and repaint as required.

(2) Clean foreign debris from seams.

(3) Test welded conduits with shielded enclosure leak detection method.

i. Grounding bonds. Test and inspect grounding bonds in accordance with the following.

(1) Inspect connections and conductors for degradation and loose connections.

(2) All electrical connections should be torqued to the proper design value.

(3) Test grounding bonds with four-point bonding method.

j. Test shielded areas. Perform a shielding effectiveness test of shielded room(s), areas, buildings, etc., using the test methods described in Institute of Electrical and Electronic Engineers (IEEE) 299, Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures.

k. Electrical filters. Inspect and test electrical filters in accordance with the following.

(1) Inspect to ensure that warning signs exist. Replace as required.

(2) Inspect enclosure for damage, openings, and corrosion of metallic objects. Repair and paint as required.

(3) Inspect air passages and remove any blockage.

(4) Inspect, investigate, and solve conditions for unusual odors.

(5) As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.

(6) Inspect electrical connections for degradation. Repair as required.

(7) Inspect electrical insulation for discoloration and degradation. Repair as required.

(8) Inspect equipment grounding system such as conductors and connections. Repair as required.

(9) Inspect insulators for damage. Replace as required.

(10) Inspect physical condition of inductors and capacitors looking for abnormalities. Capacitors should be checked for leaks.

(11) Remove debris, dirt, and other foreign deposits from all filter components, cabinets, and areas within filter cabinets.

(12) All electrical connections should be torqued to the proper design value.

(13) Test all main current carrying equipment for hot spots with an infrared temperature indicating device.

(14) Fuses, especially fuses protecting capacitors, should be checked for continuity.

(15) Verify that all access openings are tightly sealed.

(16) Test filters as described in MIL-STD-220B, Method of Insertion Loss Measurement.

l. Electrical surge arresters/protectors. Inspect and test electrical surge arresters/protectors in accordance with the following.

(1) Inspect for damage and discoloration. Replace as required.

(2) Inspect arrester air gap if applicable.

(3) Listen for unusual noises as equipment is operated or tested.

(4) Inspect, investigate, and solve conditions for unusual odors.

(5) Inspect electrical connections for discoloration and tightness.

(6) Inspect surge arrester/protector grounding system such as conductors and connections.

(7) Remove debris and dust from surge arresters and protectors.

(8) All electrical connections should be torqued to the proper design value.

(9) Test surge arresters/protectors using a high voltage transient test.

m. Electrical isolation devices. Inspect and test electrical isolation devices in accordance with the following.

(1) Inspect to ensure that warning signs exist. Replace as required.

(2) Inspect enclosure for damage, openings, and corrosion of metallic objects. Repair and paint as required.

(3) Inspect air passages and remove any blockage.

(4) Inspect, investigate, and solve conditions for unusual odors.

(5) As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.

(6) Inspect electrical connections for discoloration. Repair as required.

(7) Inspect electrical insulation for discoloration and degradation. Repair as required.

(8) Inspect equipment grounding system such as conductors and connections. Repair as required.

(9) Inspect insulators for damage. Replace as required.

(10) Inspect physical condition of inductors and capacitors looking for abnormalities. Capacitors should be checked for leaks.

(11) Remove debris, dirt, and other foreign deposits from all components and cabinet areas.

(12) All electrical connections should be torqued to the proper design value.

(13) Test all main current carrying equipment for hot spots with an infrared temperature indicating device.

(14) Fuses should be checked for continuity.

(15) Surveillance testing is done to confirm equipment operation not otherwise detectable by preventive maintenance inspections.

Table 27-1. HEMP system components

HEMP System Components	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO INSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Doors	
Clean and inspect door and window finger stock to ensure integrity.	mo
Verify that doors fit snug and are plumb.	mo
Verify doors operate smoothly.	mo
Close all doors.	mo
Test doors using continuous wave radiated field method.	mo
Honeycomb Vents	
Clean dust and other foreign debris from vents.	3 mos
Inspect mounting seams and welds to ensure integrity.	3 mos
Test vents using continuous wave radiated field method.	3 mos
Wave Guide-Below-Cutoff Devices	
Clean dust and other foreign debris from devices.	6 mos
Inspect mounting seams and welds to ensure integrity.	6 mos
Test devices using continuous wave radiated field method.	6 mos
Seams	
Inspect and test gasketed seams for the following.	
Inspect seams and gaskets for damage, openings, and corrosion. Repair and paint as required.	3 mos
Clean foreign debris from seams.	3 mos
Test gasketed seams using continuous wave radiated field method.	3 mos
Inspect and test bolted seams for the following.	
Inspect bolted seams for missing bolts, damage, openings, and corrosion. Repair and repaint as required.	6 mos
Clean foreign debris from seams.	6 mos
Test bolted seams with shielded enclosure leak detection method.	6 mos

Table 27-1. HEMP system components (continued)

HEMP System Components	
Action	***Frequency***
Inspect & test welded seams for the following.	
Inspect welded seams for damage, openings, and corrosion. Repair and repaint as required.	2 yrs
Clean foreign debris from seams.	2 yrs
Test welded seams with shielded enclosure leak detection method.	2 yrs
Conduits	
Inspect and test threaded conduits for the following.	
Inspect conduits for loose couplings, damage, openings, and corrosion. Repair and repaint as required.	yr
Clean foreign debris from couplings.	yr
Test threaded conduits with shielded enclosure leak detection method.	yr
Inspect and test welded conduits for the following.	
Inspect welded conduits for damage, openings, and corrosion. Repair and repaint as required.	2 yrs
Clean foreign debris from seams.	2 yrs
Test welded conduits with shielded enclosure leak detection method.	2 yrs
Grounding Bonds	
Inspect connections and conductors for degradation and loose connections.	yr
All electrical connections should be torqued to the proper design value.	yr
Test grounding bonds with four-point bonding method.	yr
Shielded Areas	
Perform a shielding effectiveness test of shielded rooms, areas, and buildings. (Reference 27-2*j*)	yr
Electrical Filters	
Inspect to ensure that warning signs exist. Replace as required.	yr
Inspect enclosure for damage, openings, and corrosion of metallic objects. Repair and paint as required.	yr
Inspect air passages and remove any blockage.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr

Table 27-1. HEMP system components (continued)

HEMP System Components	
Action	***Frequency***
As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.	yr
Inspect electrical connections for degradation. Repair as required.	yr
Inspect electrical insulation for discoloration and degradation. Repair as required.	yr
Inspect equipment grounding system such as conductors and connections. Repair as required.	yr
Inspect insulators for damage. Replace as required.	yr
Inspect physical condition of inductors and capacitors looking for abnormalities. Capacitors should be checked for leaks.	yr
Remove debris, dirt, and other foreign deposits from all filter components, cabinets, and areas within filter cabinets.	yr
All electrical connections should be torqued to the proper design value.	yr
Test all main current carrying equipment for hot spots with an infrared temperature indicating device.	yr
Fuses, especially fuses protecting capacitors, should be checked for continuity.	yr
Verify that all access openings are tightly sealed.	yr
Test filters per MIL-STD-220B test. [Reference 27-2*k(16)*]	yr
Electrical Surge Arresters	
Inspect for damage and discoloration. Replace as required.	yr
Inspect arrester air gap if applicable.	yr
Listen for unusual noises as equipment is operated or tested.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr
Inspect electrical connections for discoloration and tightness.	yr
Inspect surge arrester/protector grounding system such as conductors and connections.	yr
Remove debris and dust from surge arresters and protectors.	yr
All electrical connections should be torqued to the proper design value.	yr
Test surge arresters/protectors using a high voltage transient test.	yr
Electrical Isolation Devices	
Inspect to ensure that warning signs exist. Replace as required.	yr
Inspect enclosure for damage, openings, and corrosion of metallic objects. Repair and paint as required.	yr

Table 27-1. HEMP system components (continued)

HEMP System Components	
Action	***Frequency***
Inspect air passages and remove any blockage.	yr
Inspect, investigate, and solve conditions for unusual odors.	yr
As equipment is operated and tested, listen, investigate, and solve conditions for unusual noises.	yr
Inspect electrical connections for discoloration. Repair as required.	yr
Inspect electrical insulation for discoloration and degradation. Repair as required.	yr
Inspect equipment grounding system such as conductors and connections. Repair as required.	yr
Inspect insulators for damage. Replace as required.	yr
Inspect physical condition of inductors and capacitors looking for abnormalities. Capacitors should be checked for leaks.	yr
Remove debris, dirt, and other foreign deposits from all components and cabinet areas.	yr
All electrical connections should be torqued to the proper design value.	yr
Test all main current carrying equipment for hot spots with an infrared temperature indicating device.	yr
Fuses should be checked for continuity.	yr
Surveillance testing is done to confirm equipment operation not otherwise detectable by preventive maintenance inspection.	yr

CHAPTER 28

TEMPEST PROTECTION SYSTEMS

28-1. Minimum maintenance activities for TEMPEST protection systems

The information presented in this chapter indicates items that must be performed to maintain systems and equipment at a minimum level of operational readiness. Minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment.

28-2. Preventive maintenance

Preventive maintenance is a periodic checking and testing (surveillance) of equipment. Preventive maintenance defines the requirements, approaches, and procedures for maintaining TEMPEST elements, including the role of technical manuals, periodic inspections, repair activities, and repair verification. Testing defines the techniques and procedures for conducting a TEMPEST surveillance program, including grounds and bonds, shields, electrical filters, and other TEMPEST elements. Surveillance should include auditing past performance, testing current conditions, and analyzing test data. Preventive maintenance of TEMPEST protective systems is the same as those for HEMP protective systems. See chapter 27 for a detailed listing of typical maintenance activities.

CHAPTER 29

GROUNDING

29-1. Minimum maintenance activities for grounding systems

The tables located at the end of this chapter indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are summarized in table 29-1.

29-2. General maintenance procedures for grounding systems

Proper grounding provides personnel safety, affords effective equipment operation, and in some cases enables important shielding requirements. This section covers the requirements to maintain good grounds.

a. Review maintenance records. Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

b. Review operator records. Review operator records for items pertaining to the grounding system.

c. Equipment inspection. Perform a general inspection of the grounding system as described below.

(1) Inspect conductors for damage.

(2) Inspect electrical connections for degradation. Repair as required.

(3) Inspect electrical insulation for discoloration and degradation. Repair as required.

(4) Inspect for loose grounding connections. Tighten as required.

(5) Inspect for proper connection of system ground.

d. Clean equipment. Remove debris, dirt, and other foreign objects from all components and areas within resistor and reactor equipment.

e. Tighten grounding connections. All accessible grounding connections should be torqued to the proper design value.

f. Earth electrode measurements. Measure ground impedance utilizing the fall-of-potential method per American National Standards Institute/Institute of Electrical and Electronic Engineers (ANSI/IEEE) 81, "IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System." A practical application of the fall-of-potential method is described in paragraph 2.2.2.2.1 of MIL-HDBK-419A, Volume 2, Grounding, Bonding, and Shielding for Electronic Equipment and Facilities. For large systems with several grounding electrodes where the above measurements are not

practical, perform ground impedance measurements using the intersecting curves method or the slope method described in references 40 and 41 in IEEE 81.

g. Equipment ground measurements. Perform equipment ground measurements in accordance with the following.

(1) Measure critical equipment ground impedance using the two-point method of IEEE 81.

(2) Measure stray currents using a true rms ammeter. Eliminate these to the extent possible.

(3) Measure critical grounding bond resistances using test procedures described in paragraph 2.2.2.3 of MIL-HDBK-419A, Volume 2.

h. Signal reference subsystem measurements. Perform signal reference subsystem measurements in accordance with the following.

(1) Measure bond resistance in accordance with paragraph 2.2.2.3.1 of MIL-HDBK-419A, Volume 2.

(2) Measure noise current in accordance with paragraph 2.2.2.3.2 of MIL-HDBK-419A, Volume 2.

(3) Measure differential noise voltage in accordance with paragraph 2.2.2.3.3 of MIL-HDBK-419A, Volume 2.

Table 29-1. Grounding

Grounding	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review maintenance records.	yr
Review operator records.	yr
Inspect grounding system for the following.	
Inspect conductors for damage.	yr
Inspect electrical connections for degradation. Repair as required.	yr
Inspect electrical insulation for discoloration and degradation. Repair as required.	yr
Inspect for loose grounding connections. Tighten as required.	yr
Inspect for proper connection of system ground.	yr
Clean equipment.	yr
Tighten grounding connections.	yr
Earth electrode measurements.	
Measure ground impedance using the fall-of-potential method. For large systems consider using the intersecting curves method or the slope method. (Reference 29-2*f*)	
Equipment ground measurements.	
Measure critical equipment ground impedance using the two-point method of IEEE 81.	yr
Measure stray currents using a true rms ammeter. Eliminate these to the extent possible.	yr
Measure critical grounding bond resistances. [Reference 29-2*g(3)*]	yr
Signal reference subsystem measurements.	
Measure bond resistance. [Reference 29-2*h(1)*]	yr
Measure noise current. [Reference 29-2*h(2)*]	yr
Measure differential noise voltage. [Reference 29-2*h(3)*]	yr

CHAPTER 30

LIGHTNING PROTECTION

30-1. Minimum maintenance activities for lightning protection systems

Lightning protection systems include air terminals, masts, overhead ground wires, grounding and bonding conductors, connectors, ground rods, etc. as described in National Fire Protection Association (NFPA) 780, Standard for Installation of Lightning Protection Systems. The table located at the end of this chapter indicates items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are summarized in table 30-1.

30-2. General maintenance procedures for lightning protection systems

Listed below are the procedures for inspecting and testing equipment connections for their ability to prevent lightning damage. Inspection frequencies may be increased as required based on observations and experience.

a. Review maintenance records. Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

b. Review operator records. Review operator records for items pertaining to the lightning protection system.

c. Equipment inspection. Perform a general inspection of the lightning protection system as described below.

(1) Inspect electrical connections for degradation. Repair as required.

(2) Inspect structure surfaces near lightning protection system components for discoloration and degradation. Repair as required.

(3) Inspect for loose connections and components. Tighten as required.

(4) Inspect connections and components for excessive corrosion. Take corrective measures as required.

d. Tighten connections. All accessible lightning protection connections should be torqued to the proper design value.

e. Perform connection measurements. Measure earth electrode bonding and conductor impedances as described below.

(1) Perform earth electrode and bond measurements using methods described in chapter 29.

(2) Measure lightning protection conductor impedance using the two-point method of Institute of Electrical and Electronic Engineers (IEEE) 81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.

f. Recertify system (if required). A certified or labeled lightning protection system may need to be inspected occasionally by a third party and recertified. This item is included here to act as a reminder to pursue recertification if required.

Table 30-1. Lightning Protection

Lightning Protection	
Action	***Frequency***
Review maintenance records.	yr
Review operator records.	yr
Inspect lightning protection system for the following:	
Inspect electrical connections for degradation. Repair as required.	yr
Inspect structure surfaces near lightning protection system components for discoloration and degradation. Repair as required.	yr
Inspect for loose connections and components. Tighten as required.	yr
Inspect connections and components for excessive corrosion. Take corrective measures as required.	yr
Tighten connections.	yr
Perform connection measurements.	
Perform earth electrode and bond measurements using methods described in chapter 33.	yr
Measure lightning protection conductor impedance using the two-point method of IEEE 81.	yr
Recertify system (if required).	as req'd

CHAPTER 31

CATHODIC PROTECTION

31-1. Minimum maintenance activities for cathodic protection systems

The table located at the end of this chapter indicates items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this chapter are summarized in table 31-1.

31-2. General maintenance procedures for cathodic protection systems

This section covers procedures for inspection and testing cathodic protection. Inspection frequencies may be increased as required based on observations and experience. Maintenance actions apply to both impressed current and galvanic (sacrificial anode) systems unless noted otherwise.

a. Review maintenance records. Personnel should review past maintenance records to find repair patterns. These records may point to certain components that should be closely inspected during performance of preventive maintenance.

b. Review operator records. Review operator records for items pertaining to the cathodic protection system.

c. Rectifier inspection. Perform a general inspection of the rectifier (impressed current systems only) as described below.

(1) Inspect to ensure that warning signs exist. Replace as required.

(2) Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.

(3) Inspect locking devices. Repair as required.

(4) Inspect air passages and remove any blockage.

(5) Inspect electrical connections for degradation. Repair as required.

(6) Inspect mounting for proper support. Repair as required.

(7) Inspect for loose connections and components. Tighten as required.

(8) Inspect connections and components for excessive corrosion. Take corrective measures as required.

(9) During operation, listen, investigate, and solve conditions for unusual noises.

(10) During operation, inspect, investigate, and solve conditions causing unusual odors.

d. Test block inspection. Inspect cathodic protection system test blocks as described below.

(1) Inspect to ensure that warning signs exist. Replace as required.

(2) Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.

(3) Inspect locking devices. Repair as required.

(4) Inspect electrical connections for degradation. Repair as required.

(5) Inspect mounting for proper support. Repair as required.

(6) Inspect for loose connections and components. Tighten as required.

(7) Inspect connections and components for corrosion. Take corrective measures as required.

e. Tighten connections. All accessible cathodic protection connections should be cleaned and torqued to the proper design value.

f. Perform measurements. Perform system measurements as described below.

(1) On systems with impressed current, record all meter readings and compare with past readings. Investigate as required.

(2) At each test station, measure and record structure-to-soil potentials. Compare with past readings and investigate as required.

(3) At each test station, measure and record current flow for each anode. Compare with past readings and investigate as required.

(4) At each test station, measure and record anode-to-soil resistivity for each anode. Compare with past readings and investigate as required.

(5) Perform other measurements and recordings as required at test stations relating to specific conditions such as potentials between protected and other structures, or to verify intentional short circuit bonds between structures exist as installed.

(6) Perform and record structure-to-soil potential measurements on each side of insulating fittings. If voltage readings are the same, investigate for possible shorts and take corrective action.

31-3. Trouble-shooting guide

Because cathodic protection systems are static systems and do not relate to any other active system, trouble conditions will not be noticed until measurements on the system are taken. Table 31-2 lists step-by-step procedures evaluating for common trouble situations.

Table 31-1. Cathodic protection

Cathodic Protection	
Action	***Frequency***
WARNING! MAINTENANCE PERSONNEL SHALL LOCKOUT/TAG EQUIPMENT TO ENSURE DE-ENERGIZATION DURING MAINTENANCE PROCEDURES.	
Review maintenance records	yr
Review operator records	yr
Inspect rectifier for the following:	
Inspect to ensure that warning signs exist. Replace as required.	yr
Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.	yr
Inspect locking devices. Repair as required.	yr
Inspect air passages and remove any blockage.	yr
Inspect electrical connections for degradation. Repair as required.	yr
Inspect mounting for proper support. Repair as required.	yr
Inspect for loose connections and components. Tighten as required.	yr
Inspect connections and components for excessive corrosion. Take corrective measures as required.	yr
During operation, listen, investigate, and solve conditions for unusual noises.	yr
During operation, inspect, investigate, and solve conditions causing unusual odors.	yr
Inspect test blocks for the following:	
Inspect to ensure that warning signs exist. Replace as required.	yr
Inspect enclosures for damage, unauthorized openings, and corrosion of metallic objects. Repair and paint as required.	yr
Inspect locking devices. Repair as required.	yr
Inspect electrical connections for degradation. Repair as required.	yr
Inspect mounting for proper support. Repair as required.	yr
Inspect for loose connections and components. Tighten as required.	yr
Inspect connections and components for corrosion. Take corrective measures as required.	yr
Tighten connections	yr

Table 31-1. Cathodic protection (continued)

Cathodic Protection	
Action	***Frequency***
CAUTION! THE FOLLOWING MEASUREMENTS AND SUBSEQUENT EVALUATION SHOULD BE PERFORMED BY QUALIFIED PERSONNEL WHO MAY DIRECT ADDITIONAL TESTS.	
Perform system measurements as follows:	
Record meter readings and compare with past readings (impressed current systems only).	yr
Measure structure-to-soil potentials at each test station and compare with past readings.	yr
Measure current flow for each anode and compare with past readings.	yr
Measure potentials between protected and other structures as required.	yr
Verify integrity of intentional short circuit bonds between structures.	yr
Measure structure-to-soil potentials on each side of insulation fittings.	yr

Table 31-2. Trouble analysis – cathodic protection systems

Trouble	***Probable Cause***	***Corrective Action***
Low structure-to-earth potential.	Depleted anode.	Replace anode.
	High resistive conductor connection.	Remake connection.
	Changes in soil condition causing higher soil resistivity.	Evaluate present cathodic protection system design.
		Decrease resistance of anode current limiting resistor.
	High anode-to-soil resistivity.	Tamp soil surrounding anode or chemically treat area.
	Rectifier trouble.	Investigate rectifier.
Positive structure-to-earth potential.	Rectifier trouble.	Investigate rectifier.
Low anode current flow.	Depleted anode.	Replace anode.
	High resistive conductor connection.	Remake connection.
	Changes in soil condition causing higher soil resistivity.	Evaluate present cathodic protection system design.
		Decrease resistance of anode current limiting resistor.
	High anode-to-soil resistivity.	Tamp soil surrounding anode or chemically treat area.
No anode current flow.	Open circuit in anode conductor.	Perform continuity test.
	Rectifier trouble.	Investigate rectifier.
Low differential voltage at insulating fitting.	Failure of insulating materials.	Replace fitting.
	Buildup of conductive material on inside of pipe.	Remove material.
	Fitting shorted out with incidental jumper.	Investigate and remove jumper.

CHAPTER 32

BLAST PROTECTION AND DETECTION SYSTEM

32-1. Minimum maintenance activities for blast protection and detection systems

Blast protection and detection systems guard hardened facilities from the effects of an attack external to the facility. These systems consist of blast sensors, relay panels, blast valve systems, blast door systems, and the electrical system. The tables that follow indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 32-1 provides maintenance information for blast sensors and relay panels. Table 32-2 provides maintenance information for blast valve systems. Table 32-3 provides maintenance information for blast door systems.

32-2. General maintenance procedures for blast protection and detection systems

This section provides a list of minimum maintenance activities that must be performed on blast protection and detection systems. In addition, this section provides general instructions for performing the listed maintenance activities. Some equipment maintenance listed in the tables indicates that the required action is to report the status of a system or device. In these cases, the defect or discrepancy that is found cannot be corrected or repaired during the routine inspection. The facility maintenance group must plan and schedule the required repair correction.

a. Blast valve cleaning and service. There are three contributing factors to malfunctioning and deterioration of blast valves: dirt, lack of lubrication, and corrosion. Dirt, including dust, must be wiped off, and all surfaces must be kept free from oil and moisture. Dust collects on wet surfaces and forms hard coatings. Dust can combine with moisture and cause corrosion through the formation of acids, and the resultant coating would cause a reduction in bearing surface tolerances and thereby prevent optimum operation. The blast valves should be scraped and repainted, as required, to prevent deterioration. Sliding surfaces should be wiped clean and dry, then oiled and wiped lightly to remove excess oil. Non-hydraulic type blast valve spring clearances should be inspected and maintained by replacement of necessary parts. All bearings are to be lubricated with a minimum amount of lubricant, as excessive lubrication will cause a buildup of dirt and grime.

b. Hydraulic systems. All filters and strainers must be cleaned or replaced in accordance with the schedule outlined in the tables, or as indicated by system performance. Before opening a drum of hydraulic fluid, use particular care to clean the area surrounding the closure. Use a clean, lint-free wiping cloth. Use only transfer containers and hoses that have been cleaned and flushed with a recommended flushing oil prior to use. All hydraulic fluid introduced into the reservoir must be filtered through the filler strainer. Facilities using hydraulic systems may have very specific requirements for which brand and type of hydraulic fluid is acceptable for use in each system. Hydraulic fluid has unique lubricity, viscosity, seal compatibility, and temperature requirement characteristics. Be certain when adding hydraulic fluid that it is the correct brand and type. Never substitute hydraulic fluids. Hydraulic fluid breaks down after a time and combines with water and wear particles to form sludge which settles to the bottom of the reservoir. If contaminants are allowed to build up, component damage will result. Therefore, fluid condition should be

checked every six months to verify that it is suitable for further use. To check fluid condition, drain off representative samples of the fluid into clean bottles with tight fitting covers and forward it with identification and date of sample to a laboratory qualified to make a contamination analysis. If no laboratory is available, replace fluid.

(1) When visual inspection or laboratory tests indicate that the hydraulic fluid should be replaced, perform the following.

(a) Remove drain plug and drain all fluid from the reservoir.

(b) Remove access plate or cover from the reservoir.

(c) Clean interior of reservoir with solvent. Do not use rags or any material that will deposit lint to be picked up by the hydraulic fluid.

(d) Replace drain plug and fill reservoir to the high level mark.

(2) Observe the following precautions when storing the reserve supply of hydraulic fluid.

(a) Store drums of new fluid on sides rather than upright.

(b) Store drums out of the weather in a clean area.

(c) Keep containers tightly closed to avoid condensation of moisture inside and to prevent the entry of contaminants.

c. Blast door adjustments. The semiautomatic blast doors require several periodic adjustments. Typically, these adjustments are made routinely on a monthly basis. However, if the doors have been opened and closed significantly more than normal in a given period of time, these adjustments should be made more frequently. In addition, it is beyond the scope of this manual to provide specific instructions for performing each adjustment. Each facility, with semiautomatic blast doors, will have developed the specific procedures required for adjustment of the blast door systems. The adjustments required are as follows.

(1) Drive rod and chain adjustment

(2) Limit switch adjustment

(3) Electrical controls adjustment

(4) Pressure adjustment

(5) Door moving adjustment

(6) Speed control adjustment

d. Lubricate rotating equipment. Grease all zerks at the manufacturer's recommended service interval. Grease gently with a handgun to avoid damage to grease seals. Do not overgrease. Ball or roller bearings tend to heat up when overgreased and will cool down to normal running temperatures when the excess grease either oozes out or is wiped off. The normal operating temperature of a bearing may be well above

140°F, which is "hot" to touch. Temperatures should be checked with a thermometer, and any temperature readings over 180°F should be questioned. If a drop of water placed on a bearing sizzles, the bearing is in distress and should be changed before it seizes and ruins the shaft. During equipment overhauls, bearing assemblies should be thoroughly cleaned, inspected, and adjusted in accordance with the manufacturer's recommendations. All old grease should be removed from bearings, and the bearings should be repacked with grease a minimum of every two years. For sleeve bearing assemblies with oil reservoirs, service reservoirs at the manufacturer's recommended interval with recommended viscosity lubricating oil. Do not overfill reservoir as overheating may result. When new sleeve bearing units are placed in service, drain and flush the oil reservoir after about two weeks of operation and refill the reservoir with new lubricating oil of the proper viscosity. Monitor the operation of all recently installed bearings. Check for overheating (alignment and lubrication), vibration (alignment), loose collars, fasteners, etc. Early problem detection can avoid early failure and costly replacement.

e. Packing adjustment. Occasional packing adjustment may be required to keep leakage to a slight weep; if impossible to reduce leakage by gentle tightening, replace packing. A slight weeping through the packing gland is required so that the process fluid provides lubrication for the packing material. Maintain a supply of the recommended type and size of packing required for the equipment. Do not substitute one type of packing with another without verifying the packing types are compatible. Do not use oversized packing. If diameter of oversized packing is reduced by hammering, early failure of packing may result. A too tight packing joint may interfere with equipment operation, can damage equipment, and, again, may result in early failure of the packing. The procedure to follow when replacing packing is as follows.

(1) Remove all old packing.

(2) Inspect shaft for wear and replace as required.

(3) Use proper size packing, and cut packing into rings using the shaft as a guide. When cutting to length, hold packing tightly around shaft, but do not stretch packing. Cut with a butt joint. **Do not wind packing around shaft.**

(4) Thoroughly clean shaft and housing.

(5) Install one ring at a time. Oil or grease lubrication, if permitted, will assist when packing the ring into the box. Offset joints of each succeeding ring by at least 90 degrees from the previous ring.

(6) If shaft is equipped with a lantern ring, be sure that the lantern ring is slightly behind lubrication hole in stuffing box, otherwise the lantern ring will move forward when the gland is taken up and the packing behind the ring may plug the lubrication hole.

(7) Tighten the gland bolts all the way to seat the packing. Then loosen the nuts until the nuts are finger tight. In most applications, newly installed packing should be allowed to leak freely on startup. After startup, tighten packing gland until only 2 to 3 drops a second are leaking. **Do not try to stop leakage entirely.** The leakage lubricates the packing and prevents early failure of the packing and shaft.

f. Rotating equipment clearance adjustment. After long service, the running clearances in some types of rotating equipment (fans, pumps, compressors, etc.) may increase to the point where the device is losing capacity or pressure. Resetting the clearances will normally improve performance. Check clearances during annual inspections and adjust as required. Refer to the manufacturer's Technical Service Manual.

g. Examine internal parts of rotating equipment. Periodically (at least annually) remove casing access covers and inspect components for wear. Replacing a relatively inexpensive part after only moderate wear can eliminate the need to replace more expensive parts at a later date. Refer to the manufacturer's Technical Service Manual.

h. Flexible coupling installation and alignment. These instructions cover, in general, the installation of flexible couplings of the pin, gear, or grid types. When aligning shafts, a general rule is to align large motor shafts so the center of the motor shaft is 0.001 inch lower than the driven shaft for each 1 inch of motor shaft diameter. Turbine shafts or similar large rotating equipment, as a general rule, are set 0.001 inch lower than the driven shaft for each 1 inch of height from the mounting feet to the center of the shaft. This initial offset provides for thermal expansion of the equipment. After the equipment has been in operation long enough to reach operating temperature, the alignment of the shafts should be checked and adjusted as required.

(1) Verify that equipment the coupling is serving is completely assembled and adjusted before installing drive coupling.

(2) Install each half cover with seals on its shaft. Consult the coupling manufacturer's data to determine proper orientation of long and short shanks of coupling.

(3) For non-taper lock hub units, heat coupling to approximately 300°F by means of a hot oil bath or oven. **Do not apply flame to hub teeth.**

(4) Install coupling hubs on motor and driven shafts. Install shaft keys while hubs are still hot. Face of hub should be flush with end of shaft.

(5) Adjust the clearance between the coupling faces. Consult manufacturer's data for proper clearance. (Some coupling units may have required clearance stamped on coupling unit.)

(6) When a sleeve bearing motor is used, locate motor so that when the motor rotor is closest to the driven shaft, the motor shaft will not touch the driven shaft. If the motor shaft has a magnetic center marked, base clearance between coupling faces on magnetic center. Otherwise, determine maximum motor shaft movement and base clearance between coupling faces on one half the motor shaft movement.

(7) With tapered wedge, feeler gauges, or dial indicator verify that faces of coupling hubs are parallel.

(8) Using a straightedge or dial indicator, verify that motor and driven shafts are parallel. Shim and adjust as required.

(9) After alignment of shafts is obtained, recheck spacing between hub faces and verify that faces are parallel to within 0.001 inch.

(10) When alignment is complete, thoroughly clean both sides of the coupling and inspect all parts for damage. Install the gasket and draw the coupling flanges together keeping gasket holes in line with bolt holes. Insert and tighten bolts, and lock washers and nuts. Lubricate coupling in accordance with the manufacturer's data.

i. Clean all equipment. Clean all equipment regularly. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

Table 32-1. Blast sensors and relay panels

Blast Sensors and Relay Panels	
Action	***Frequency***
Blast Sensors	
Inspect plenum opening for obstruction and blockage.	mo
Check pressure plate for free movement.	mo
Check microswitch for free plunger operation	mo
Check microswitch for moisture, and check moistureproofing around wiring connections.	mo
Disconnect microswitch to check with ohmmeter. When piston is depressed with appropriate force (approx. 12 pounds), the microswitch should open showing infinite resistance reading across the switch contacts. If adjustment is required, follow the procedures listed following the table section	mo
Relay Panels	
Clean external surfaces of panels. Repair rusty or corroded spots as necessary.	mo
Open panels; vacuum internal areas with a soft brush attachment.	mo
Examine internal components and wires for signs of deterioration, overheating, or corrosion. Schedule an outage for a time that would be convenient to perform work in the panel and correct deficiencies accordingly.	mo

Table 32-2. Blast valve systems

Blast Valve Systems	
Action	***Frequency***
Blast Valve Piping	
Check all hydraulic lines and fittings for condition, leakage, mounting, and security	week
Blast Valves	
Check for leakage of hydraulic fluid inside the blast valves.	week
Check hydraulic fluid level in shock absorbers. Replenish as necessary	mo
Power Units	
Check fluid level in the hydraulic power units reservoirs.	week
Drain off accumulated sludge and water from reservoir.	600 op hrs
Collect fluid samples for analysis.	6 mos
Check system hydraulic pressure on gauges at the power units.	week
Inspect discharge filters at the power units; replace as required.	week
Inspect suction strainers in pump suction lines in power unit reservoir. Clean as required.	3 mos
General	
Check for compressed air leaks in piping and valves. Noise will be a good indication.	week
Inspect compressed air filter element in supply lines to Hydraulic-Electric-Pneumatic (HEP) boxes. Replace as required.	6 mos
Inspect relay panels for loose wires and burned contacts, and to ensure that the interposing relay contacts that bypass the blast sensors are open.	week
Accumulators	
Check accumulator precharge pressure; recharge if pressure is below 1,500 psig.	mo
Power Unit Electric Motors	
Lubricate bearings.	yr
Inspect; keep motors clean and ventilation openings clear.	week
Inspect starter contacts, clean or replace as necessary	6 mos
Inspect starter wiring for cracks, cuts, and abrasions; replace as necessary and correct cause of damage.	6 mos
Valve Operators	
Cycle to insure proper operation. Visually verify valve position and check position indication at any remote panels.	mo

Table 32-3. Blast door systems

Blast Door Systems	
Action	***Frequency***
General	
Inspect the following blast door items:	
Outside surfaces of locking pins for rust.	week
Machined surfaces of doors and frames for rust.	week
For blast doors with hydraulic systems, inspect blast doors for the following:	
Check hydraulic lines and fittings for leaks. Check hydraulic filters for dirty condition; replace as required. Check reservoir oil level and oil for dirty condition.	week
Inspect pump coupling for wear, tightness, alignment, and unusual noise or excessive vibration. Check pump motor for cleanliness and overheating.	week
Check drive rod and chain for excessive slack, sprocket and chain for wear and lubrication, and cylinder mounting bolts for tightness.	week
Lubrication	
The blast door hinge bearings should be lubricated with medium weight bearing lubricating grease.	yr
The locking pins should be lubricated with a few drops of a light rust-preventive lubricating oil. Lightly lubricate all bearing and sliding surfaces. After lubricating, operate the locking pins several times to lubricate the locking pin bushings.	mo
For Manual Doors Only: Remove the hand wheel and sheet metal cover over each locking pin mechanism, and lubricate the sliding parts of the gears, guides, etc., with a medium weight grease.	2 yrs
For Hydraulically Operated Doors: With door closed, remove sprocket cover. Check sprocket teeth for wear and lightly lubricate. Lubricate chain and bearing plates. Remove chain, dip-clean in solvents, dry, and lubricate (yearly).	mo

CHAPTER 33

FIRE PROTECTION

33-1. Minimum maintenance activities for fire protection systems

The tables that follow indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer recommended maintenance activities and procedures for specific pieces of equipment. Halon systems are being phased out or are already removed from service. Maintenance of these systems will not be addressed. Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 33-1 provides maintenance information for automatic sprinkler systems. Table 33-2 provides maintenance information for dry pipe sprinkler systems. Table 33-3 provides maintenance information for carbon dioxide systems. Table 33-4 provides maintenance information for detection and alarm systems.

33-2. General maintenance procedures for fire protection systems

Equipment maintenance is the responsibility of both operating and maintenance personnel. Many of the items required by this section are performed as an operator routinely monitors and logs the operation of the system. Some equipment maintenance listed in the tables at the end of this chapter indicates that the required action is to report the status of a system or device. In these cases, the defect or discrepancy that is found cannot be corrected or repaired during the routine inspection. The facility maintenance group must plan and schedule the required repair or correction. Finally, the facility operator should use the following as a guide in conjunction with the maintenance manuals for equipment installed at the facility to develop a comprehensive maintenance plan for the facility.

a. Facility review. Preventive maintenance of a sprinkler system includes periodic reviews of the protected area to ensure that no changes have occurred that would interfere with the fire protection efficiency of the system, such as the following.

(1) Change of occupancy increasing the hazard beyond the original design criteria of the system.

(2) Sprinkler heads that were inadvertently painted or received paint spots when the area was painted.

(3) Change in storage arrangement that could affect the sprinkler discharge.

(4) Control valves obscured by equipment or construction.

(5) Sprinkler system equipment, devices, or heads damaged by vehicles or motorized equipment.

(6) Sprinkler head discharge obstructed by new construction.

(7) Shift in machinery or equipment that could damage the sprinkler heads.

b. Automatic sprinkler systems. Automatic sprinkler systems may be classified as “wet-pipe” or “dry-

pipe." Wet-pipe systems are permanently piped water systems that use heat-actuated sprinkler heads to discharge water on a fire. Dry-pipe systems utilize heat-actuated sprinkler heads attached to a piping system containing air under pressure. When a sprinkler operates, the air pressure is reduced, a dry-pipe valve is opened by water pressure, and water flows to any opened sprinklers.

(1) Sprinkler heads that have been in service for 50 years must have representative samples removed and submitted to a testing laboratory that is acceptable to the authority having jurisdiction for operational testing, and this procedure should be repeated every 10 years.
Sprinkler heads should be visually checked periodically for corrosion, paint, or damage. If any of these conditions are found, heads should be replaced.

(a) If changes in occupancy have changed the temperature in the protected area, the temperature rating of the existing sprinkler heads should be verified, and heads with too low a temperature rating should be replaced with higher temperature heads to accommodate the highest anticipated temperature. The addition of new machinery or equipment that is heat producing will require that the new maximum temperatures be obtained to determine if the temperature rating of the existing sprinkler heads is adequate. It may be necessary to provide a recording thermometer if the machinery is not operated continuously. This type of thermometer is similar to the medical thermometer that will record the highest temperature and remain at this reading until shaken down. Solder type sprinkler heads with a high temperature rating that are exposed to a periodic, or continuous, maximum allowable ambient temperature condition should be tested at least every five years. Remove approximately 1 percent of the heads on a system and submit them to a testing laboratory acceptable to the authority having jurisdiction for testing. Sprinkler heads that are exposed to a periodic, or continuous, maximum temperature condition can become weakened and the solder fusible element can fail. This is especially true of heads that are classified with an extra-high temperature rating, such as 365^{o}F.

(b) Corrosion-resistant sprinklers installed in areas where the heads are subject to corrosive fumes or chemicals must be periodically checked to determine if the corrosion-proof material coating the head is intact and the head is not coated with foreign material. Any corrosion-proof head with the corrosion-proof material damaged must be replaced with a new corrosion-proof head. Attempts to salvage a damaged corrosion-proof head by recoating is prohibited.

(c) Replacement of heads found to be defective, damaged, or painted must be with new heads of the same temperature rating and position (upright or pendent), and if corrosion-proof with the same corrosion-proof coating, used heads shall not be acceptable.

(d) If the area protected with automatic sprinklers is to be painted, the sprinkler heads shall be covered with polyethylene or cellophane bags having a thickness of 0.003 inch or less, and bags shall be removed when painting is completed. Heads exposed to painting or spraying areas where they may collect overspray should be checked for collection of residue. The heads should be covered with the bags, and these coverings should be replaced or heads cleaned frequently. If not covered as described, the heads should be replaced annually.

(2) Sprinkler piping and hangers should be maintained in a good condition and free from mechanical injury. Sprinkler piping should be checked periodically to prevent the piping from being used to support ladders, stock, or other material. Where piping and hangers are installed in areas subject to a corrosive atmosphere, a protective coating that resists corrosion must be provided and the piping and hangers maintained in a proper condition. Broken or loose hangers should be replaced or refastened. When the age of a sprinkler system warrants, an internal examination of the piping should be made, and if corrosion or foreign material is found to be present, the system should be flushed. The flushing of a sprinkler system

requires the services of a sprinkler contractor with experienced workmen and the proper flushing equipment.

(3) The gauges on a wet pipe sprinkler system should be checked monthly to ensure that the system is under normal water supply pressure. Gauges on a dry pipe system (pre-action and deluge systems) should be checked weekly to ensure that the required air and water pressure is being maintained. All systems gauges should be checked with an inspector's gauge every five years. There should be a ¼-inch valve and plug on the gauge supply line to facilitate the installation of the inspector's gauge.

(a) On dry pipe systems, a leak rate which drops the system pressure by more than 10 psig (0.7 bar) per week requires immediate repair.

(b) Increase system pressure to 50 psig and locate leaks by scanning system with a sonic leak detector; painting joints and fittings with a glycerin and soap solution; or introducing wintergreen into the piping system. Alternatively, the system may be hydrostatically tested if there is no chance of freezing.

(4) All water flow alarm devices should be tested quarterly, weather permitting, and this is best accomplished by opening the inspector's test connection and discharging a flow equivalent to one sprinkler operating. When freezing weather does not permit the operation of the inspector's test connection discharging to the atmosphere on the building exterior wall, there is a bypass test connection on the trim of the alarm valve and dry pipe valve which may be used to test the alarm devices.

(5) The approach of freezing weather mandates the checking of all system drains and all piping that may contain water that is exposed to freezing conditions. The ½-inch automatic ball check drain on the fire department pumper line must be checked for proper operation. All drains on the dry pipe system must be checked to make certain that no condensation water has collected. Drum drip drains on the dry pipe systems must be emptied. It is expedient to check to make certain that windows, skylights, doors, ventilators, and other openings are not exposing wet sprinkler piping to freezing weather. This exercise should also include blind spaces, unused attics, stair towers, etc., which are subject to freezing temperatures. The low-point drains on a dry pipe system should be drained frequently to remove all moisture, and this process should be repeated daily until all condensate water has been positively removed.

(6) The air pressure on each dry pipe system should be checked at least once a week, and should be maintained at a pressure recommended by the dry pipe valve manufacturer. If there is leakage of air pressure exceeding 10 psi per week, repairs are mandated.

(7) Dry pipe valves should be trip-tested with the control valve wide open at least once every three years. This test is conducted by opening the inspector's test connection and the inspector's test run until it has been determined that the dry pipe valve has tripped and clean water is flowing from the inspector's test outlet. The dry pipe valve should be cleaned and parts renewed as required following this test, and the dry pipe valve should be reset. Use the following procedure to trip test dry pipe valves.

(a) With water supply shut off, trip test dry pipe valve and quick opening devices. During test, allow condensate to drain from system, and clean and maintain dry pipe valve as required. Reset valve and system.

(b) With water supply on, trip test system by opening inspector’s test connection. Verify that appropriate alarms are activated as pressure is released and the flow of water is initiated.

(c) If water flow from inspector’s test connection does not appear within 60 seconds, check

piping for closed valves or obstructions and excessive air pressure in system. If neither of the above, system should be evaluated for installation of an accelerator or an exhauster.

(d) Prior to initiating the wet trip test, flush the supply system by fully opening the main drain and allowing water to discharge at full pressure to clear any accumulations of scale or other foreign material. If a hydrant takes supply from the system main, flush hydrant before opening main drain.

(e) When wet trip is completed, thoroughly drain the system. Remove the dry pipe valve cover plate. Determine if valve operation was normal by position of parts. Thoroughly wash inside of valve body and wipe clappers with a clean cloth. Remove all dirt and scale with special attention to small valves or ports to drains and alarm devices. If rubber seats or rings are deformed, cracked, or in generally poor condition, replace with new parts.

(8) The air compressor should be kept clean and all filters cleaned as required, and crystals in air dryers should be replaced when the color changes indicating that they have absorbed moisture.

(9) The following are conditions that may indicate the need for investigation of the interior of the piping or valves.

(a) Discharge of obstructive material during routine water tests.

(b) Foreign material in dry pipe valves, alarm valves, check valves, and control valves.

(c) Heavy discoloration of water during drain tests or plugging of the inspector's test connection.

(d) Plugging of the sprinklers.

(e) Plugged piping in the sprinkler piping during alterations to the sprinkler system.

(f) Abnormally frequent tripping of the dry pipe valve.

(g) Dry pipe systems found obstructed should be flushed and re-examined at not more than five-year intervals.

(h) Where conditions are favorable, dry pipe systems should be examined at 10-year intervals after installation.

(10) All control valves, both interior and on underground mains, should be periodically operated and, if necessary, greased for ease of operation. Electric tamper switches should be tested during the opening and closing of control valves.

(11) Fire department pumper connections should be inspected monthly, and must remain unobstructed and visible. Caps or plugs should remain in place with threads in good working condition, check valve not leaking, and waterway visually free of foreign material. No new construction or equipment shall be installed in a position to limit the operation of the hose wrenches when attaching the 2 1/2-inch fire hose.

(12) All hose stations should be inspected at least monthly to verify that all equipment is in place and in good condition. Hose racks or reels and nozzles should be checked for visible signs of mechanical

damage or deterioration, and hose station control valves should be checked for signs of leakage.

(13) The sprinkler cabinet should be checked during system inspection to determine if the cabinet contains the required number of each type of sprinkler and temperature ratings that are used on the system. The sprinkler cabinet shall also contain at least one sprinkler wrench suitable for each type of sprinkler used on the system. Location of cabinets will minimize exposure to excessive moisture, dust, corrosion, or temperatures exceeding 100^{o}F.

c. CO_2 extinguishing systems. CO_2 extinguishing systems use a limited stored supply of CO_2 under pressure, in conjunction with a permanently piped system of discharge nozzles, to totally flood an enclosed area. The agent, released automatically by a suitable detection system, extinguishes fires by reducing the oxygen content of air below combustion support. **Personnel must be evacuated before agent discharge to avoid suffocation.**

(1) A manufacturer's test and maintenance program should be instituted, and at least annually, all carbon dioxide systems should be thoroughly inspected and tested for proper operation by competent personnel. The goal of this inspection and testing should be to not only ensure that the system is in full operating condition, but also indicate the continuance of that condition until the next inspection. An inspection report with recommendations must be submitted to the owner. Between regular service contract inspections or tests, the system shall be inspected visually by competent personnel. Weight and the date of the last hydrostatic test shall be noted.

(2) At least semiannually, all high-pressure carbon dioxide cylinders shall be weighed and the date of the last hydrostatic test shall be noted. If a CO_2 container shows a loss in net content of more than 10 percent, the cylinder shall be refilled or replaced.

(3) Weekly, the liquid level gauges of low-pressure CO_2 containers shall be observed. If a container shows a loss of more than 10 percent, it shall be refilled.

(4) All system hoses, including those used as flexible connectors on carbon dioxide systems, shall be examined annually for damage. If visual inspection indicates any deficiency, the hose shall be replaced or tested at 2,500 psi for high-pressure systems and 900 psi for low-pressure CO_2 systems. All hose systems, including those used as flexible connectors, shall be tested every five years.

(5) Carbon dioxide system detection and alarm systems shall be tested at least annually. All detectors shall be cleaned in a manner prescribed by the manufacturer at least annually. Ionization detectors may require cleaning more frequently if installed in an atmosphere subject to dust. Manufacturer's recommendations shall be followed for testing, cleaning, and maintenance of detection and alarm systems.

d. Detection and alarm systems. Preventive maintenance of fire detection and alarm systems is essential to ensuring automatic fire suppression systems operate properly when needed.

(1) Manual alarm initiating devices encountered in a facility may include non-coded and coded manual pull stations; pre-signal and general alarm stations; breakglass and non-breakglass stations; single and double action stations; key operated manual stations; and addressable manual stations. The function of each should be tested in accordance with manufacturer’s recommendations to verify that operation of the device sends the proper signals to alarm and system actuation devices.

(2) Heat detectors are generally located on or near the ceiling and actuate as a result of the convected thermal energy of a fire. They respond either to a specified rate of temperature change, or when the detecting element reaches a predetermined fixed temperature.

(a) Fixed temperature, non-restorable, line type units shall be mechanically and electrically tested to verify operation. Measure and record loop resistance of line type detectors and compare with original acceptance test values.

(b) Fixed temperature, non-restorable spot type detectors shall be laboratory tested for function. Submit two units per 100 installed to a recognized testing laboratory. Replace submitted units with new units of same type and rating. Follow laboratory recommendations for additional maintenance and replacement.

(c) Fixed temperature and/or rate-of-rise and rate compensation restorable line or spot type detectors (not pneumatic tube) shall be tested with heat source such as a hair dryer or shielded heat lamp. Testing only 10 percent of the units at each test cycle is required. Plan testing so that all units are tested over any five-year span. Avoid damage to non-restorable fixed temperature element of combination rate-of-rise and fixed temperature detectors.

(d) Pneumatic tube restorable line type detectors shall be tested with a heat source.

(3) Verify function of smoke detectors by calibrated test method using manufacturer's calibrated sensitivity instrument. Ordinary pressurized test aerosols, or smoke from cigarettes or similar sources shall not constitute a test.

(4) Post indicator valve and gate valve tamper switches shall be tested by operating the valve and verifying that the proper trouble signal is activated.

(5) Low air pressure device on dry pipe and supervised pre-action systems shall be tested for transmission of appropriate trouble signal.

(6) Using system test features, verify proper operation of audible and visual alarms.

(7) Using system test features, verify operation of all lamps and light-emitting diodes (LEDs). Remove and inspect fuses and verify fuse rating.

(8) Test main power supply by disconnecting all secondary (standby) power and test under maximum load, including all alarm appliances operating for five minutes.

(9) Test secondary (standby) power supply by disconnecting all primary power supplies. Verify that required trouble indication for loss of primary power is operational. Measure system's standby current and compare with manufacturer's data for determining whether batteries are adequate to meet standby requirements. Test under maximum load, including all alarm devices operating for five minutes. Reconnect primary (main) power supply at end of test.

(10) Sealed lead acid batteries are not vented since the gas evolved during recharging is internally recombined. A high pressure vent is provided to avoid damage during abnormal conditions. Typical maintenance activities include the following.

(a) Check open-circuit voltage. Measure battery voltage under full load conditions with battery charger disconnected. Clean all connections. Check operation of battery charger.

(b) Replace batteries as required.

(11) Although traditional wet-cell vented lead acid batteries require more maintenance than sealed battery systems, they are still used in applications with relatively high current drain requirements. Typical maintenance activities include the following.

(a) Visually inspect electrolyte level and connections. Add electrolyte and clean connections as required.

(b) Measure open-circuit voltage.

(c) Measure specific gravity.

(d) Measure battery voltage under full load conditions with battery charger disconnected. Clean and coat battery connections. Check open-circuit voltage. Check operation of battery when recharged battery voltage or specific gravity falls below manufacturer recommendations.

(12) Nickel-cadmium batteries are generally used where current drain during a primary power outage is low to moderate. Typical maintenance activities include the following.

(a) Measure open-circuit battery voltage. Clean and inspect battery connections.

(b) Measure output voltage and current of battery charger. Measure battery voltage under full load conditions with battery charger disconnected. Check operation of battery charger. Replace battery when recharged battery voltage or current falls below manufacturer's recommendations.

(13) Verify operation of panel trouble signals and ring-back feature for systems using a trouble silencing switch which requires resetting.

Table 33-1. Automatic sprinkler systems

Automatic Sprinkler Systems	
Action	***Frequency***
Control Valves	
Check sealed valves to verify valve is sealed in open position and seal is unbroken	week
Check locked valves and valves equipped with electric tamper switches to verify valve is open, and lock is not broken or tamper switch is not damaged.	mo
Lubricate valve stems, and exercise valves to verify operation and distribute lubrication.	yr
Post Indicator Valve	
Exercise valves. Open until spring or torsion is felt in the rod and back-off one quarter turn from wide open position to prevent jamming.	3 mos
Underground Gate Valves with Roadway Boxes	
Exercise valves. Operate each valve using a T-handle wrench to verify valve is in proper position.	3 mos
Verify roadway box is readily accessible and that cover is in place.	3 mos
Verify that installed signs are not obstructed and that information is legible	3 mos
Fire Department Pumper Connection	
Verify that connection is both visible and accessible at all times.	mo
Verify that all caps and plugs are in place and threads are in good condition. Remove caps and plugs and verify that waterway is free of all foreign material. The presence of water indicates check valve may be leaking and/or ball drip may not be functioning properly.	mo
Verify that ball drip or drain is in working order.	mo
Inspect for leakage into piping beyond check valve. Continual drip from ball drip or drain is indication that check valve may be leaking.	mo
Sprinkler	
Inspect area protected by sprinkler system for the following:	
Any changes in use which require higher temperature rating sprinklers.	mo
Piled material stocks are at least 18 inches below sprinkler heads.	mo
No new construction or equipment is blocking heads.	mo
Clean sprinkler heads protected by a polyethylene or cellophane bag (0.003 inch thickness or less) and replace protective bags.	mo
Inspect all sprinkler heads for the following:	

Table 33-1. Automatic sprinkler systems (continued)

Automatic Sprinkler Systems	
Action	***Frequency***
Corrosion – If due to normal aging, replace with new head of same type and rating. If due to operation in area emitting corrosive vapors, replace with factory-applied lead or wax-coated corrosion resistant heads.	3 mos
Paint or similar coating applied to head in field – Replace head.	3 mos
Light corrosion, dirt, or other foreign material – clean head to like new condition, or replace head as required.	3 mos
Head guards for accessible sprinklers are in place and any sprinkler showing evidence of mechanical damage is replaced.	3 mos
Inspect spare sprinkler cabinet	
Replace heads that have been removed.	3 mos
Verify that sprinkler wrench is present.	3 mos
Verify that cabinet contains at least one replacement head for each size, type, and rating of head used in the facility.	3 mos
Verify that temperature where cabinet is located does not exceed 100°F (38°C).	3 mos
For sprinklers with fusible links protecting commercial type cooking equipment and associated ventilation systems:	
Inspect and clean, and replace as required.	6 mos
Replace.	yr
Replace sprinklers protecting spraying areas where the heads are not protected by polyethylene or cellophane bags.	yr
Test a representative sample of all solder type sprinkler heads with a temperature rating of extra high (325°F or 163°C). Testing shall be by an approved testing laboratory. Minimum sample is four per riser or 1 percent of the total heads, whichever is greater. Follow laboratory recommendation for additional maintenance or replacement.	5yr
Test a representative sample of all sprinklers every 10 years.	10 yrs[1]
Hangers	
Visually inspect system for broken or loose hangers, and repair or replace as required.	3 mos
Piping	
Visually inspect piping for:	
Mechanical injury. Repair or replace as required.	3 mos

Table 33-1. Automatic sprinkler systems (continued)

Automatic Sprinkler Systems	
Action	***Frequency***
Piping being used to support equipment or devices (ladders, other pipes, conduit, clothing, etc.) which are not part of system. Eliminate condition immediately.	3 mos
Gauges	
Check system pressure.	mo
Remove gauge and verify pressure with test gauge. Service and replace gauge.	5 yrs
Alarms	
Test alarms in nonfreezing weather by opening inspector's test connection to provide flow equivalent to one sprinkler head.	3 mos
Test alarms in freezing weather, by opening by-pass test connection on alarm valve.	3 mos
Water Motor Alarm	
Test alarm in nonfreezing weather by opening inspector's test connection to provide actual flow.	3 mos
In freezing weather, do not flow test. Verify by inspection that parts are free and drain is not clogged.	3 mos
Supply Test	
Open main drain valve and note pressure gauge readings when full flow is obtained. Compare reading with reading before opening valve and with previous readings when system was flow tested. Variations in readings may indicate closed valves or obstructions in supply pipe.	3 mos
Freeze Prevention	
Inspect system to verify that windows, skylights, doors, ventilators, or other openings and closures will not unduly expose sprinkler piping to freezing. Blind spaces, unused attics, stair towers, and concealed spaces shall be inspected and action taken as required to prevent freezing temperatures from occurring.	

[1] After 50 years in service.

Table 33-2. Dry pipe sprinkler systems

Dry Pipe Sprinkler Systems	
Action	***Frequency***
Dry Pipe Valve	
Check priming water level by use of the priming water level test valve to maintain level required by the manufacturer.	3 mos
Trip test system	yr
Supply Water Flow Test	
Open main drain and allow water to flow for a short period of time to ensure water supply to system is available.	3 mos
Low Air Alarm	
Test low air alarm for proper function.	3 mos
Pressure Gauges	
Observe system pressure gauge(s) to ensure recommended pressure is being maintained.	week
Dry Pipe Valve Enclosure	
Inspect to ensure that the thermostatic heater system is functioning properly and maintaining a temperature in the enclosure of not less than 40°F (4°C).	week[1]
Water Flow Alarms	
Using alarm test by-pass, test water flow alarms – pressure switch and water motor alarm. **Do not test water motor alarm in freezing weather.**	3 mos
Auxiliary Drains	
Drain water from all low point drains:	
As freezing weather approaches and first few days of freezing weather.	day
During freezing weather.	week
Pipe Pitch	
Inspect piping to detect low points which may trap water. Verify pitch with spirit level as required.	yr[2]
Intermediate Chamber Drain	
Inspect intermediate chamber drain to verify free operation of drain assembly.	mo
Air Compressor	
Inspect compressor for the following:	

[1] During freezing season
[2] After trip test and before freezing weather.

Table 33-2. Dry pipe sprinkler systems (continued)

Dry Pipe Sprinkler Systems	
Action	***Frequency***
Clean dirt from motor.	3 mos
Clean or replace filters and strainers as required.	3 mos
Replace desiccant if required (change in color of desiccant).	3 mos
Air Maintenance Device	
Inspect and clean strainers, filters, and restriction orifices. If drain cock provided, drain condensation	3 mos
Quick-Opening Devices (Accelerator/Exhauster)	
Test quick opening devices in accordance with the manufacturer's instructions. If device does not test properly, immediately replace the device with a new unit.	6 mos

Table 33-3. Carbon dioxide systems

Carbon Dioxide Systems	
Action	***Frequency***
Low Pressure System	
Check and record storage tank level. Loss in net content of more than 10 percent mandates refilling, unless minimum requirements for primary and reserve supply are still available in the container.	week
Inspect valve packing glands, screwed connections, safety relief valves, and similar piping components for leaks and repair as required.	mo
Maintain tank refrigeration equipment in accordance with manufacturer's recommendations.	per mfg
Test operation of tank alarm pressure switch and operation of alarm bell and/or light by decreasing and increasing the system pressure. Pressure may be reduced by closing the valve in the line from the vapor space and removing the test plug. Pressure may be increased by connecting a high-pressure cylinder to the test opening. At completion of testing, test plug shall be carefully replaced and vapor line valve reopened.	6 mos
Check liquid level and tank pressure gauges for accuracy.	yr
Replace storage tank frangible disks.	5 yrs
High Pressure System	
Weigh and record weight of all high pressure cylinders. If cylinder weight indicates a net content loss of 10 percent, it shall be replaced.	6 mos
Inspect all system hoses and components associated with connecting hoses such as flexible connectors for damage. Replace any hose or component showing evidence of any damage of deficiency.	yr
Inspect all cylinder brackets and supports. Replace any bracket or support component showing evidence of any damage or deficiency.	yr
Pressure test all system hoses and components associated with connecting hoses such as flexible connectors. Testing shall be performed by a recognized testing organization using equipment and procedures in accordance with NFPA requirements.	5 yrs
Piping – High and Low Pressure Systems	
Inspect piping for evidence of corrosion. Piping showing severe corrosion shall be replaced.	yr
Nozzles – High and Low Pressure Systems	
All nozzles shall be examined to verify that orifices are clear and unobstructed. Any nozzle that is obstructed or plugged by corrosion or foreign material that cannot be cleaned to like new condition shall be replaced with a new nozzle of the same type and orifice size.	yr

Table 33-3. Carbon dioxide systems (continued)

Carbon Dioxide Systems	
Action	***Frequency***
Check nozzles for proper position and alignment.	yr
For sealed unit nozzles, inspect seal for any sign of deterioration. Replace any nozzle where weal shows evidence of any damage, deterioration, or other deficiency	yr
Detectors	
All detectors shall be individually inspected for corrosion or foreign material. If detector cannot be cleaned to like new condition, replace detector.	yr
Detection System	
Verify operation of detection system control and alarm functions in accordance with the manufacturer's recommendations.	yr
Detection and Actuating Systems	
Verify operation of automatic system actuation controls and devices. Remove automatic actuating controls from cylinders. Simulate a fire condition at each detector and observe that actuating control devices move to the "discharge" position.	yr
System Operating Devices	
Verify operation of manual system actuation controls and devices. With automatic actuating controls deactivated, operate each manual system operating device (manual Pull stations, switches, abort switches, etc.) and observe that the actuating controls move to the "discharge" position.	yr
Total Flood System Time Delay	
With the automatic actuating controls deactivated, operate the time delay device. Also check that the timer will complete its cycle even though wiring between time and detector circuit is interrupted. Check time limit.	yr
Alarm System	
During simulated fire activation of detectors with automatic system actuating controls deactivated, verify function of all alarm devices including transmission of remote alarm signals.	yr
Auxiliary Equipment	
During simulated fire activation of detectors with automatic system actuating controls deactivated, verify proper operation of all magnetic door holders, window releases, HVAC unit interlocks, damper releases, operation of interlocked valves and solenoids, and supplementary alarms.	yr
Power Supply	
Inspect wiring, circuit breakers, fuses, disconnects, and similar electrical components and replace any damaged components or components which do not properly operate.	yr

Table 33-3. Carbon dioxide systems (continued)

Carbon Dioxide Systems	
Action	***Frequency***
Check condition of emergency power supply (battery condition) and operation of battery charger. Verify operation of automatic switch over from main electric service to battery backup.	yr
Selector Valves	
Exercise all selector (directional) valves. Reset to proper position when exercise completed.	yr
Signs	
Check to determine that all warning signs are properly displayed, and all manual pull station functions are clearly indicated.	mo
Explosive Release Devices	
Inspect condition of charges and expiration of charge. Replace charge prior to expiration date.	3 mos
System Integrity	
Visually inspect protected area for changes (construction configuration, change in occupancy, change in hazard, addition of equipment, etc.) that could affect original design criteria or carbon dioxide concentration.	yr
Visually check for changes in protected area that could affect efficiency of detectors or nozzle discharge.	yr
Visually check protected area to identify doors blocked in open position, and unclosable openings in walls, floors, and ceilings. Initiate corrective action immediately.	yr

Table 33-4. Detection and alarm systems

Detection and Alarm Systems	
Action	***Frequency***
Manual Pull Stations – With/Without Break Glass	
Test function in accordance with manufacturer's recommendations. Verify that operation of switch sends proper signals to alarm and system actuation devices.	6 mos
Double Action Manual Stations	
Test function in accordance with manufacturer's recommendations. Verify that operation of switch sends proper signals to alarm and system actuation devices.	6 mos
Key Operated Manual Stations	
Test function in accordance with manufacturer's recommendations. Verify that operation of switch sends proper signals to alarm and system actuation devices.	6 mos
Key Operated Pre-Signal Manual Stations	
Test function in accordance with manufacturer's recommendations to verify activation of pre-signal alarm.	6 mos
Test function in accordance with manufacturer's recommendations to verify general alarm signal and system actuation signal.	yr
Coded Manual Stations	
Test function in accordance with manufacturer's recommendations. Verify that operation of switch sends proper signals to alarm and system actuation devices.	6 mos
Addressable Manual Stations	
Test function in accordance with manufacturer's recommendations. Verify that operation of switch sends proper signals to alarm and system actuation devices.	6 mos
Heat Detectors	
Fixed temperature, non-restorable, line type units shall be mechanically and electrically tested to verify operation. Measure and record loop resistance of line type detectors and compare with original acceptance test values.	6 mos
Fixed temperature, non-restorable spot type detectors shall be laboratory tested for function. Submit two units per 100 installed to a recognized testing laboratory. Replace submitted units with new units of same type and rating. Follow laboratory recommendations for additional maintenance and replacement.	5 yrs
Fixed temperature and/or rate-of-rise or rate compensation restorable line or spot type detectors (not pneumatic tube) shall be tested with heat source such as a hair dryer or shielded heat lamp. Testing only 10 percent of the units at each test cycle is required. Plan testing so that all units are tested over any five-year span. Avoid damage to nonrestorable fixed temperature element of combination rate-of-rise and fixed temperature detectors.	6 mos

Table 33-4. Detection and alarm systems (continued)

Detection and Alarm Systems	
Action	***Frequency***
Pneumatic tube restorable line type detectors shall be tested with a heat source.	6 mos
Smoke Detectors	
Verify function by calibrated test method using manufacturer's calibrated sensitivity instrument. **Ordinary pressurized test aerosols, smoke from cigarettes or similar sources shall not constitute a test.**	yr
Valve Tamper Switch	
Post indicator valve and gate valve tamper switches shall be tested by operating the valve and verifying that the proper trouble signal is activated.	6 mos
Low Air Pressure Alarm	
Low air pressure device on dry pipe and supervised pre-action systems shall be tested for transmission of appropriate trouble signal.	6 mos
Low Temperature Alarm	
Low temperature alarm device shall be tested to activate the appropriate trouble signal should the temperature drop below a predetermined point.	6 mos
Audible and Visual Alarms	
Using system test features, verify proper operation of audible and visual alarms.	yr
Control Panel	
Using system test features, verify operation of all lamps and LEDs. Remove and inspect fuses and verify fuse rating.	yr
Primary Main Power Supply	
Test main power supply by disconnecting all secondary (standby) power and test under maximum load, including all alarm appliances operating for five minutes.	yr
Secondary (Standby) Power Supply	
Test secondary power supply by disconnecting all primary power supplies. Verify that required trouble indication for loss of primary power is operational. Measure system's standby current and compare with manufacturer's data for determining whether batteries are adequate to meet standby requirements. Test under maximum load, including all alarm devices operating for five minutes. Reconnect primary (main) power supply at end of test.	yr
Sealed Lead Acid Batteries	
Check open-circuit voltage. Measure battery voltage under full load conditions with battery charger disconnected. Clean all connections. Check operation of battery charger.	yr

Table 33-4. Detection and alarm systems (continued)

Detection and Alarm Systems	
Action	***Frequency***
Replace batteries.	4 yrs
Lead Acid Batteries	
Visually inspect electrolyte level and connections. Add electrolyte and clean connections as required.	week
Measure open-circuit voltage.	6 mos
Measure specific gravity.	6 mos
Measure battery voltage under full load conditions with battery charger disconnected. Clean and coat battery connections. Check open-circuit voltage. Check operation of battery when recharged battery voltage or specific gravity falls below manufacturer recommendations.	yr
Nickel-Cadmium Batteries	
Measure open-circuit battery voltage. Clean and inspect battery connections.	3 mos
Measure output voltage and current of battery charger. Measure battery voltage under full load conditions with battery charger disconnected. Check operation of battery charger. Replace battery when recharged batter voltage or current falls below manufacturer's recommendations.	yr
Trouble Signals	
Verify operation of panel trouble signals and ring back feature for systems using a trouble silencing switch which required resetting.	yr

APPENDIX A

REFERENCES

Required Publications

Government Publications

Department of Defense:

MIL-HDBK-419A
Grounding, Bonding, and Shielding for Electronic Equipment and Facilities (Cited in para 29-2f, 29-2g(1), 29-2g(3), 29-2h(1), 29-2h(2), 29-2h(3), table 29-1.)

MIL-STD-220B
Method of Insertion Loss Measurement (Cited in para27-2k(16), table 27-1)

Department of the Army:

TM 5-692-2
Maintenance of Mechanical and Electrical Equipment at C4ISR Facilities, System Design Features (Cited in para 1-1)

Non-Government Publications

American Society for Testing and Materials (ASTM):
100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ASTM D 91
Standard Test Method for Precipitation Number of Lubricating Oils (1997) (Cited in para 6-2a(2)(g))

ASTM D 117
Standard Guide for Sampling, Test Methods, Specifications, and Guide for Electrical Insulating Oils of Petroleum Origin (1996) (Cited in para 20-2e(2)(4))

ASTM D 877
Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes (1995) (Cited in para 20-2e(2)(a), table 20-5)

ASTM D 1524
Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field (1999) (Cited in para 20-2e(2)(c), table 20-5)

ASTM D 1534
Standard Test Method for Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration (1995) (Cited in para 20-2e(2)(b), table 20-5)

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

IEEE 43
Recommended Practice for Testing Insulation Resistance of Rotating Machinery (2000) (Cited in para 19-2b(1)(a))

IEEE 81
Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (1983) (Cited in para 29-2f, 30-2e(2), table 29-1, table 30-1)

IEEE 299
Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures (1997) (Cited in para 27-2j, table 27-1)

IEEE 400
Guide for Making High-Direct-Voltage Tests on Power Cable System in the Field (1991) (Cited in para 20-2d(2)(c), table 20-4)

IEEE 450
Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications (1995) (Cited in para 22-2q(1), table 22-1)

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

NFPA 780
Standard for Installation of Lightning Protection Systems (1997) (Cited in para 30-1)

APPENDIX B

MAINTENANCE TOOLS

B-1. Tool inventory

The following lists serve as guides for supplying maintenance personnel with tools. Requirements for both basic and trade tools will vary depending on the equipment served and on individual preferences.

a. Standard tools – basic. The following tools are commonly used by all trades.

(1) Standard and phillips head screw drivers - various sizes

(2) Pliers - vise grip (2), slipjoint, needlenose, diagonal, cutting pliers, side cutters

(3) Ball peen hammer

(4) Hack saw and spare blades

(5) 3/8" drive socket set and ratchet

(6) Small set of Allen wrenches

(7) Assorted center punches, drift punches, steel chisel

(8) 12' measuring tape

(9) Crescent wrenches 4" to 8"

(10) Open and box end wrenches 1/4" to 3/4"

(11) File

(12) Pipe wrenches to 14"

(13) Small level and square

(14) Pocket knife

(15) Flashlights

(16) Grease guns and oilers

(17) Wire brush

(18) Shears and tin snips

(19) Extension cord and inspection lights

(20) Various cleaning tools - brushes, scrapers, etc.

(21) Emery cloth

(22) Handsaws

(23) Paint brushes and containers

(24) C-clamps, various sizes

(25) Drill and bits

(26) Star wrenches

b. HVAC/refrigeration/mechanical tools. The following tools are commonly used by refrigeration mechanics.

(1) Standard tools - basic

(2) Refrigeration - gauges

(3) Refrigerant recovery equipment

(4) Leak detector - electronic or halogen

(5) Voltmeter - Ohmmeter - Milliammeter (True RMS)

(6) Flaring tool

(7) Tubing cutters

(8) Clamp-on ammeter (True RMS)

(9) Packing kit and packing

(10) Crescent wrenches to 14"

(11) Head pressure gauge registering 0-400 psig

(12) Compound pressure gauge registering from 30 inches vacuum to 150 psig

(13) Gauge manifold with flexible lines

(14) Refrigerant charging hose

(15) Refrigerant service cylinder

(16) Scales for weighing refrigerant charge or charging cylinder

(17) Valve stem wrenches

(18) Leak detector

(19) Vacuum pump

(20) Refrigerant grade thermometers

(21) Bearing, hub, and gear puller

(22) Gauge feeler

(23) Torque wrenches (common need is 5 ft-lb to 500 ft-lb range)

(24) Pocket thermometer

(25) Flaring tool

(26) Dial indicator gauge

(27) Hand grease gun

(28) Collet driver

(29) Shaft locating tool

(30) Portable A-frame and chain hoist

(31) Vernier calipers and micrometers

(32) Flat and tapered feeler gauge set

(33) Hydraulic arbor press

(34) Oil charging pump

(35) Sheet gasket cutting tool set

(36) Tap and die set

c. *Electrician's tools.* The following tools are commonly used by electricians.

(1) Standard tools - basic

(2) Insulated pliers and screwdrivers

(3) Wire strippers

(4) Wire crimpers

(5) Voltmeter - Ohmmeter - Milliammeter (True RMS)

(6) Clamp-on ammeter (True RMS)

(7) Soldering kit

(8) 1/8" X 25' fish tape

(9) Burnishing tool

d. Pipefitter/plumber tools. The following tools are commonly used by pipefitters and plumbers.

(1) Standard tools - basic

(2) Pipe wrenches to 24"

(3) Tubing cutters

(4) Flaring tool

(5) Small acetylene outfit

(6) Package kit and packing

(7) 3/4" socket set

(8) Crescent wrenches to 14"

(9) Pipe cutting and threading tools

e. Portable power tools. All trades may utilize the following portable power tools during maintenance activities.

(1) Drills

(2) Grinders

(3) Saws

(4) Paint sprayers

B-2. Tool care and usage

Tools have specific uses and must not be used for other purposes. When the proper tool is not available, it should be obtained.

a. Tool storage. Tools should be kept on a tool board or in a tool-box when not in use.

b. Tool inspection. Tools must be inspected monthly. Damaged or worn tools must be replaced, and cutting tools must be kept sharp. Tools should be cleaned and lubricated before they are returned to storage.

GLOSSARY

Abbreviations

AC
Alternating Current

ANSI
American National Standards Institute

ASME
American Society of Mechanical Engineers

ASTM
American Society for Testing and Materials

C4ISR
Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance

C
Centigrade

CBR
Chemical, Biological, and Radiological

cm
Centimeter

CI
Cast Iron

CP
Cathodic Protection

CPU
Central processing unit

d
day/days/daily

DC
Direct Current

DCS
Distributed control system

DOD
Department of Defense

DX
Direct Expansion

EM
Electromagnetic

EMP
Electromagnetic Pulse

EP
Engineer Pamphlet

ESS
Electronic Security System

F
Fahrenheit

ft
Feet

HAD
Heat Actuator Detector

HEMP
High Altitude Electromagnetic Pulse

HEPA
High Efficiency Particulate Air

hr
hour/hours/hourly

HVAC
Heating, Ventilating, and Air Conditioning

IEEE
Institute of Electrical and Electronics Engineers

K
Thousand

kg
Kilogram

km
Kilo Meter

kVA
Kilo Volt Amperes

kW
Kilo Watts

LED
Light-emitting diode

mo
month/months/monthly

NFPA
National Fire Protection Association

O&M
Operations and Maintenance

PLC
Programmable logic controller

ppm
Parts Per Million

psig
Pounds Per Square Inch, Gage

R/A
Reliability/Availability

RMS
Root Mean Square

s
Second

sh
every shift

TM
Technical Manual

UPS
Uninterruptible Power Supply

VAR
Volt-Ampere Reactive

wk
week/weeks/weekly

The proponent agency of this publication is the Chief of Engineers, United States Army. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) directly to HQUSACE, (ATTN: CEMP-SP), Washington, DC 203 14- 1000.

By Order of the Secretary of the Army:

ERIC K. SHINSEKI
General, United States Army
Chief of Staff

Official:

/JOEL B. HUDSON
Administrative Assistant to the
Secretary of the Army

Distribution:

To be distributed in accordance with Initial Distribution Number (IDN) 344719, requirements for non-equipment TM 5-692- 1.

PIN: 078972-000