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21 February 2018
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UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE (O&M): GENERATORS

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UNIFIED FACILITIES CRITERIA (UFC)

OPERATION AND MAINTENANCE (O&M): GENERATORS

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U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

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

Change No.	Date	Location
1	5 Nov 2019	Updated the Summary Sheet, Chapters 1, 2, 3, 5, and 8 (Chap. 8 formerly App. C) and App. A (formerly App. D); renumbered former Appendices A and B as Appendices B and C. Numerous non-substantive corrections throughout for format, grammar, missing/outdated references, and paragraph numbering; these changes are not marked.

This UFC supersedes Engineering Technical Letter (ETL) 13-4, *Standby Generator Design, Maintenance, and Testing Criteria.*

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and, in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and the Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing Service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective Service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet site below.

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

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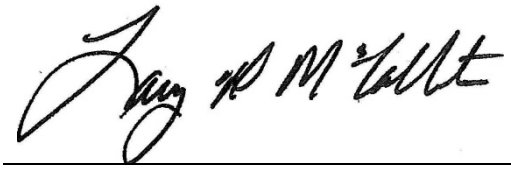
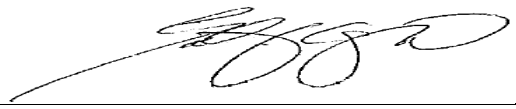


LARRY D. McCALLISTER, PhD, PE, PMP, SES
Chief, Engineering and Construction
Directorate of Civil Works
U.S. Army Corps of Engineers

JOSEPH E. GOTT, P.E.
Chief Engineer
Naval Facilities Engineering Command



EDWIN H. OSHIBA, SES, DAF
Director
Air Force Civil Engineer Center

MICHAEL McANDREW
Deputy Assistant Secretary of Defense
(Facilities Investment and Management)
Office of the Assistant Secretary of Defense
(Energy, Installations, and Environment)

UNIFIED FACILITIES CRITERIA (UFC)
SUMMARY SHEET

Document: UFC 3-540-07, *Operation and Maintenance (O&M): Generators*

Superseding: Air Force ETL 13-4, *Standby Generator Design, Maintenance, and Testing Criteria*

Description: UFC 3-540-07 provides guidance for O&M of standby, emergency, and prime power generators.

Reasons for Document: Provide guidance for O&M of generators.

Impact: There are no impacts on design and initial cost, energy savings, or life cycle costs.

\1\ Unification Issues: Air Force-only requirements are in Chapter 8. **/1/**

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Proper O&M of generators is essential to ensuring continuous electrical system operation and reliability. A comprehensive O&M program with proven practices and well-performed maintenance prevents downtime and mission loss or delay.

1-2 PURPOSE AND SCOPE.

This UFC provides the minimum guidance and standards for O&M of standby, emergency, and prime power generators and is intended to be used by operations and maintenance personnel. It includes safety requirements, standard operating instructions, maintenance instructions, and test procedures. This UFC is intended to be used with the generator manufacturer's recommended operational procedures and maintenance manuals.

1-3 APPLICABILITY.

The guidance and standards contained within are the minimum requirements acceptable for military installations for efficiency, economy, durability, maintainability, and reliability of generator systems. The provided guidance does not automatically supersede equipment manufacturers' instructions and requirements. When conflicts exist, follow the most rigorous requirement. The guidance and standards herein are not intended to be retroactively mandatory. Provide, as a minimum, the level of maintenance required to meet critical mission reliability goals.

- Comply with the requirements of 29 CFR 1910, *Occupational Safety and Health Standards.*
- Comply with the requirements of Title 40 CFR 1 to 1100, *Environmental Protection Agency*.
- Comply with UFC 3-550-01, *Exterior Electrical Power Distribution*, for minimum system and component design standards.
- Comply with UFC 3-520-01, *Interior Electrical Systems*.
- Comply with UFC 3-560-01, *O&M: Electrical Safety*, for electrical safety requirements applicable to the installation and operation of electrical systems.
- Comply with UFC 3-540-01, *Engine-Driven Generator Systems for Backup Power Applications*, for backup power applications.

\1\ Note: The Air Force will follow operations, maintenance, and testing requirements outlined in Chapter 8. ***/1/***

1-4 SAFETY.

1-4.1 Minimizing Hazards.

Before starting maintenance, be aware that a generator can start without warning and cause serious injury or death. Use lockout/tagout (LOTO) procedures and wear appropriate personal protective equipment (PPE). Comply with UFC 3-560-01 for electrical safety requirements.

Apply standard operating procedures (SOP), where available, for reducing/minimizing/eliminating potential hazards with PPE, proper training, and rescue procedures and equipment.

1-4.2 Qualifications of Generator and Electrical Workers.

1-4.2.1 Training.

Generator and electrical workers must be qualified through training and demonstrated skills and knowledge in specific hazards associated with their potential exposure in accordance with OSHA requirements and safety-related practices contained in NFPA 70E, *Standard for Electrical Safety in the Workplace*, and IEEE C2, *National Electrical Safety Code (NESC)*. Trained and qualified generator and electrical workers must be familiar with the following:

- The skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment.
- The skills and techniques necessary to determine the nominal voltage of exposed live parts.
- The clearances specified in NFPA 70E and IEEE C2.
- Operating (starting, running, shutdown procedures) and maintaining generators, generator synchronizers, generator control system, fuel system, cooling system, exhaust system, and switchgear.

1-4.2.2 Generator Workers and Operators.

Maintain a list of qualified generator operators. The generator operator and worker must have the knowledge to monitor indicating devices that reflect system operation and manipulate controls necessary to properly start, operate, and shut down generator equipment. Ensure the facility manager or others (operators) at the facility are trained to operate and check generator status. It is the responsibility of the facility or mission owner to request annual training from the base civil engineer (BCE)/Public Works as required.

1-5 CYBERSECURITY.

Operate and maintain all generator-related control systems to maintain compliance with the network system authorization as required by DoDI 8500.01, *Cybersecurity*, and

DoDI 8510.01, *Risk Management Framework (RMF) for DoD Information Technology (IT)*. See UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*, for additional information.

\1 [Deleted note.] ***/1/***

1-6 PERSONNEL SAFETY.

Generator and electrical workers must wear proper safety clothing in the work area per OSHA 1910.132. Workers must be trained and certified in use and care of PPE, insulating protective equipment (IPE), and LOTO controls. Personnel must follow safety procedures, conduct hazard analyses, and attend job safety briefings in accordance with OSHA and UFC 3-560-01 safety requirements. Proper tools must also be used in accordance with 29 CFR 1926. Electrical gloves must be tested according to ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves*. NAVFAC must also follow local specific regulations.

1-7 REFERENCES.

Appendix B contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance or edition of the reference is used.

1-8 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

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CHAPTER 2 GENERATOR CONFIGURATION

2-1 GENERAL REQUIREMENTS.

Maintenance of the generator consists of all systems associated with the generator, including cables, prime movers, and ancillary equipment.

Note: There are differences between the EPA and NFPA definitions for an emergency generator and generator operators must ensure they are using the correct reference within each context to avoid misunderstandings.

2-2 RECIPROCATING ENGINE PRIME MOVER.

There are two primary types of reciprocating engines: compression ignition and spark ignition. Compression ignition includes diesel fuel engines. Spark ignition includes gasoline, natural gas, and liquid petroleum gas (LPG) engines.

The major components of reciprocating engine requiring maintenance include:

- Engine block assembly (block, crankshaft, pistons and rings, camshaft, lifters, connecting rods, intake and exhaust valves, and cylinder heads)
- Fuel system
- Cooling system
- Exhaust system
- Lubrication system
- Starting system
- Battery and charging system
- Automatic transfer switch (ATS)
- **\1** Manual transfer switch (MTS) **/1/**
- Ignition system
- Air intake system
- Control system
- Exercise

2-3 GENERATOR.

2-3.1 AC Generator.

AC generators used are synchronous except for wind turbines.

2-3.2 Mechanical.

The mechanical portion of a generator system consists of the fuel system, starting system (either pneumatic or electric), lubrication system, cooling system, and intake/exhaust system.

2-4 FUEL SYSTEM.

A common reason for generators not starting is a clogged fuel filter due to old or contaminated fuel; therefore, the fuel filters and fuel must be checked as part of routine maintenance.

2-5 LUBRICATING SYSTEMS – RECIPROCATING ENGINES.

Reciprocating engine lubrication system components requiring maintenance typically include:

- Sump/oil tank
- Lubrication filter
- Lubrication cooler
- Oil pump
- Tubing, hoses, and fittings

On larger size engines, the clean oil tank, waste oil tank, and pre-lubrication pumps are separate and require maintenance.

2-6 ENGINE COOLING SYSTEMS.

Engine water cooling system components typically requiring maintenance include water pumps, radiator, thermostat, cooling fan, hoses, thermostats, and instrumentation.

2-7 INTAKE AIR AND EXHAUST SYSTEMS.

2-7.1 Intake Air.

The intake air system cleans the air entering the generator engine or turbine. Air filtration systems for reciprocating engines typically use weather protection and final filters.

Intake air system components typically requiring maintenance include filters, filter housings and air intake horns, dampers, damper actuators, inertial separators, moisture coalescers, anti-icing systems, and instrumentation.

2-7.2 Exhaust System.

The exhaust system removes the combustion gases from the engine. Exhaust system components that typically require maintenance include draining the condensate and examining the manifold for leaks and holes.

2-8 DC POWER AND CHARGING SYSTEM.

Two types of batteries are vented cell batteries and sealed cell batteries. The vented, or open, batteries require periodic liquid levels observation and refilling, as necessary. Lead calcium flooded batteries have typical lifetimes of 20 years. **\1** Sealed cell, valve regulated lead acid (VRLA) batteries generally recommended are versions of sealed wet cell or absorbent glass mat (AGM). ***/1/*** Pure lead versions of these batteries have lifetimes over four years. A lifetime cost analysis must be done to choose what type batteries are required for the application. Maintenance must be included in these calculations. Load test all batteries according to IEEE 450, *Recommended Practice for Maintenance, Testing, and replacement of Vented Lead-Acid Batteries for Stationary Applications*. According to manufacturers, the top two reasons standby generators fail to automatically start or run are that the generator START switch is in the OFF position instead of AUTO or the starting batteries are dead or insufficiently charged.

2-9 AC POWER DISTRIBUTION SYSTEM.

Refer to UFC 3-550-01 for exterior electrical power distribution.

2-10 AUTOMATIC TRANSFER SWITCHES (ATS).

Most standby and emergency generators will have an associated ATS that requires maintenance. Those systems that do not have an ATS will have switchgear that accomplishes the same result or synchronizes with the utility. The ATS is an integral part of a generator system and must be tested to ensure proper operation. Refer to UFC 3-540-01 for design requirements.

2-11 MANUAL TRANSFER SWITCHES (MTS).

MTSs must be maintained by visually inspecting for rust and corrosion and ensuring moving components are greased with electrically conductive grease. They must also be exercised during generator system testing.

2-12 GROUNDING SYSTEMS.

Grounding systems should be visually inspected during generator inspections and testing for physical continuity for separately derived systems is required every two years (specifically at expeditionary sites).

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CHAPTER 3 DEVELOPING AN O&M PROGRAM

3-1 O&M MANAGEMENT.

3-1.1 Administration and Structure.

The O&M administration structure must include the elements of operations, maintenance, engineering support, training, and administration. Operations is responsible for management and control of operation activities, equipment control and status, and operator knowledge and performance to support safe and reliable operations. Maintenance is responsible for effective management and control of maintenance activities, efficient performance of the work control system, safe conduct of maintenance activities, and maintenance procedures and documentation. Engineering support ensures effective implementation and control of technical support, equipment modifications, equipment performance monitoring, and engineer support of procedures and documentation. The Commanding officer, in conjunction with the generator subject matter expert (SME), must implement and control training activities, general training, maintenance training, operations training, training facilities, and equipment. Administration plans and implements policies, develops management objectives to improve performance, monitors activities, oversees industrial safety, and ensures personnel are appropriately trained.

Operational testing/operation must be done per the manufacturer's recommendations. NFPA 110, *Standard for Emergency and Standby Power Systems*, also specifies emergency generator testing requirements. This includes full-load generator testing and exercise of circuit breakers and switches.

Note: The Air Force will follow the test requirements in Chapter 8.

3-1.2 Quality Assurance Program.

The O&M quality assurance program must measure the quality or effectiveness of the quality assurance program. Each plant is recommended to have a quality assurance plan to ensure the maintenance program is effective; however, it is not a minimum requirement.

3-1.2.1 Quality Assurance Metrics.

Use the following metrics to measure the quality or effectiveness of the quality assurance program:

- Plant reliability
- Work orders generated and closed out
- Corrective maintenance backlog
- Safety record
- Environmental record

- Energy use
- Inventory control
- Overtime worked
- Absentee rate
- Staff turnover

3-1.2.2 Base Period.

Track performance metrics on a periodic basis but not less than monthly.

3-1.3 Contracted Maintenance.

During the warranty period, the manufacturer must be contacted for resolution. Technicians will have documented training/experience on maintaining assigned generators. The contracted maintenance must include a submittal of a preventive maintenance schedule that meets or exceeds the generator manufacturer's recommended requirements.

3-2 TRAINING.

Fully train all personnel to perform O&M on specific installed generators. At a minimum, train personnel on the following:

- O&M of the equipment
- Proper use of tools, protective equipment, and precautionary techniques
- Electrical hazards associated with electrical equipment
- Techniques and skills to practice O&M activities on electrical equipment
- Job planning
- Maintaining a safe work environment
- Familiarization of the one-line electrical connection diagram/control diagrams for specific generator facility connection and layout

3-2.1 Qualifications of Generator Workers.

Personnel must be fully qualified/trained to perform O&M on generators and must follow/obey safety procedures in their work area.

3-2.1.1 Electricians.

Electrical workers must be trained and qualified to operate and maintain the electrical switchgear, including relays and circuit breakers, switchgear control system, transformers, DC power system, and other electrical ancillary equipment.

3-2.2 Safety.

Safety considerations must be taken into account to maintain the generators in accordance with UFC 3-560-01 and, for the Air Force, AFI 32-1064, *Electrical Safe Practices*. This involves access to generators, location of generators, tool locations, grouping of equipment, spacing requirements dictated by manufacturer's instructions, and NEC Article 110.

3-3 TOOLS AND EQUIPMENT.

3-3.1 Electrical Tools and Equipment Standards.

Industry standards describe the requirements for electrical protective equipment and tools. **\1** These standards were developed so tools, equipment, materials, and test methods used by electrical workers will provide protection from electrical hazards. Tool and equipment terminology and in-service maintenance and electrical testing are included in IEEE 935, *IEEE Guide on Terminology for Tools and Equipment to Be Used in Live Line Working*, and IEEE 516, *IEEE Guide for Maintenance Methods on Energized Power Lines*, respectively. ***/1/*** UFC 3-560-01 also contains tool and equipment requirements. In case of conflict, always use the most stringent safety requirement.

3-3.2 Standard Tools and Equipment.

For simplicity and convenience, the tools and equipment required for electrical inspection and maintenance are classified as follows:

3-3.2.1 Tools.

Tools include hand tools, digging tools, hot line tools, miscellaneous and special tools, and tackle.

3-3.2.2 Protective Equipment.

Protective equipment includes required PPE, such as eye and hearing protection, helmets, gloves, footwear, and arc flash clothing, and non-PPE items such as LOTO locks, barricades, and warning devices. Follow PPE requirements in UFC 3-560-01 and, for the Air Force, AFI 32-1062, *Electrical Systems, Power Plants and Generators*.

3-3.2.3 Large Portable and Mobile Equipment.

Large portable and mobile equipment includes relatively large and easily transportable equipment for use in maintenance work, such as line trucks, aerial lift trucks, motor-generator sets, posthole diggers, load banks, and similar apparatus.

3-3.3 Care and Storage of Tools and Equipment.

Tools and equipment will be kept in proper operating condition and used only for the purpose for which they were designed. If proper and safe tools are unavailable, report tool needs to a supervisor.

Inspect all tools at regular intervals and any tool that develops defects when in use will be taken from service, tagged, and not used again until restored to proper working condition.

3-3.4 Electrical Inspecting and Testing Equipment.

The number and types of testing/inspection devices needed depends on local needs. When available, follow the manufacturer's instructions for the care and maintenance of test equipment. Schedules for calibrating and testing instruments and meters are dependent upon the particular installation. When precision is not essential, the period between tests is not critical and may be assigned as convenient. For units provided with built-in diagnostic capabilities, check diagnostics when their associated power apparatus is checked.

3-3.4.1 Maintenance of Instruments, Meters, and Test Equipment.

Only personnel trained and qualified to maintain instruments, meters, and test equipment, or personnel under the immediate supervision of such qualified personnel, are allowed to perform accuracy tests, repairs, calibrations, and adjustments of instruments and meters. When selecting meters, match meter accuracy to the requirements of which the reading and records are being used. Procuring equipment with higher accuracy than requirements dictate must be economically justified.

3-3.4.2 Frequency of Inspections.

If calibration standards and equipment are not available, instruments and meters of nearly the same rating can be checked against each other. When wide discrepancies are noted or the instrument or meter is obviously incorrect, recalibrate and make any needed repairs.

3-3.4.3 Test Instrument Calibrations.

Calibrate instruments according to manufacturer's recommendations and agency requirements.

- Air Force: Perform calibration in accordance with AFI 21-113, *Air Force Metrology and Calibration (AFMETCAL) Management*, and T.O. 00-20-14, *Air Force Metrology and Calibration Program*.
- Army: Perform calibration in accordance with U.S. Army Test, Measurement, and Diagnostic Equipment Activity (USATA) requirements, AR 750-43, *Army Test, Measurement, and Diagnostic Equipment*, and TB

43-180, *Calibration and Repair Requirements for the Maintenance of Army Materiel*.

- Navy and Marine Corps: Perform calibration in accordance with the NSWC Corona Measurement Science and Technology Laboratory Measurement and Calibration (METCAL) program.

3-3.5 Required Electrical Safety Program.

Implement and document an overall electrical safety program that directs activity appropriate for the electrical hazards, voltage, energy level, and circuit conditions. Refer to NFPA 70E and UFC 3-560-01.

Note: For the Air Force, see AFMAN 91-203, *Air Force Occupational Safety, Fire, and Health Standards*, and AFI 32-1064.

3-4 HAZARDOUS MATERIAL PROCEDURES.

Implement a hazard communication program in accordance with 29 CFR 1910.1200 or 29 CFR 1926.59 and DoDI 6050.05, *DoD Hazard Communication (HAZCOM) Program*, as amended by agency guidance. The major hazardous items to which electrical workers may be exposed are asbestos, polychlorinated biphenyls (PCBs), sulfur hexafluoride (SF6), and some of the chemicals used to control undesirable brush or pests or to preserve wood. For PCBs, comply with 40 CFR 761 and DoD 4715.05-G, *Overseas Environmental Baseline Guidance Document* (OEBGD).

Note: For the Air Force, see AFMAN 91-203.

3-5 SYSTEM DATA, EQUIPMENT DATA, AND DOCUMENTATION.

3-5.1 Operating Procedures.

Operating procedures must be documented and readily available. Mandatory testing, validation, approval, and review requirements must be kept in a permanent or appropriate record for the various types of generator configurations.

3-5.2 Manufacturer O&M Manuals.

Ensure manufacturer O&M manuals, parts manuals, and technical manuals/orders (if applicable) are always available and in a convenient location for access. Manufacturer manuals provide essential guidance on recommended frequency for inspections and maintenance for generators. Ensure at least one set of O&M manuals are supplied by the generator manufacturer at the time of acquisition.

3-5.3 Derating.

If something has changed on the generator, such as moving it from one location to another, and therefore the altitude, secondary fuel, or environmental conditions change, the generator must be de-rated **\1** by the authority having jurisdiction (AHJ) for each

Service. This de-rating must be documented in the O&M manuals and properly labeled. **/1/**

3-5.4 Installation Drawings.

Ensure at least two sets of installation drawings are provided by the installation contractor and maintained by the shop to give guidance to the operator and maintainer on equipment installation and other related activities. Circuit drawings must be updated with any modifications by the responsible party as required by NFPA 70E and 29 CFR 1910.

3-5.5 Control Diagrams.

Control diagrams are functional representations of the interconnection of the electrical equipment and contain one-lines, schematics, and wiring diagrams. They include the required content, format, and verification process for control diagrams for the operator and maintainer.

3-5.6 Maintenance Forms and Records.

Record maintenance information and test data for generators on Service-approved forms and checklists. Forms serve as an equipment inspection guide or checklist in order to maintain the generators in optimum working condition. Retain records for the Service-defined period of time and make available to the AHJ, as requested. Figures 3-1, 3-2, and 3-3 are typical maintenance forms to use for generator inspection activities.

Figure 3-1 Engine Generator Inspection Checklist

ENGINE GENERATOR INSPECTION

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT _____
EQUIPMENT LOCATION _____
CIRCUIT IDENTIFICATION _____

ENGINE TYPE: ☐ GASOLINE ☐ DIESEL ☐ GAS TURBINE

MAKE _____ MODEL _____ SERIAL NO. _____ KS # _____
KVA _____ KW _____ VOLTAGE _____ F.L.A. _____
RPM _____ HZ _____ HP _____ TECH. BULL. # _____

1. ☐ Change oil and lube oil filters.
2. ☐ Remove unused oil from premises.
3. ☐ Change fuel oil elements.
4. ☐ Service crankcase breather.
5. ☐ Inspect air cleaner element, clean if required. If replacement is required, element(s) will be billed separately. Price of element(s) not included in contract price.
6. ☐ Check coolant level and maintain safe degree of protection. Engine mounted radiators only. (Remote radiators, cooling towers & heat exchangers serviced at user's request on a time and material basis.)
7. ☐ Check manifolds, brackets, mountings and flex connections.
8. ☐ Inspect fan belts, adjust if required.
9. ☐ Check pulley hub, bearings, lubricate if required.
10. ☐ Check operation of auxiliary water pump or fan motor.
11. ☐ Check operation of automatic louvers.
12. ☐ Repair minor fuel, coolant and lube oil leaks.
13. ☐ Check operation of jacket water heater(s).
14. ☐ Inspect generator, perform any routine maintenance as required.
    ☐ Megger
15. ☐ Inspect governor/actuator linkage.
16. ☐ Check battery electrolyte level and maintain to include:
    ☐ Temperature ☐ Specific Gravity ☐ Voltage
17. ☐ Check operation of charger and/or alternator.
18. ☐ Inspect fuel supply system for leaks or low level, inform owner of any discrepancies.
19. ☐ Drain condensation from day tank and check for any contamination. ONLY if day tank is equipped with a drain valve.
20. ☐ Check operation of transfer pump.
21. ☐ Check for correct generator output voltage & frequency, adjust if required.
22. ☐ Simulate & check operation of each safety shutdown and alarm device, relay type control panels only.
23. ☐ Check operation of generator control instrumentation; volts, amps, etc.
24. ☐ Test fault lamps & replace bulbs as required, panels with lamp test only.
25. ☐ Tank crankcase oil sample, owner to be notified of any discrepancies.
26. ☐ Submit report to owner
27. ☐ Auto start test.

REMARKS _____

SUBMITTED BY _____ EQUIPMENT USED _____

Courtesy of Northeast Electrical Testing NFPA 70B

Figure 3-2 Generator Set Survey

GENERATOR SET SURVEY

Date: _____

Installation: _____ Location: _____

Number of generator sets at this location: _____

Generator Set #1

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair
❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: _____

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: _____
- Model/Type: _____ Rated Voltage: _____
- Rated hp (or kW): _____ Rated Current: _____
- Power Factor: _____ Frequency: _____

Generator Data:

- Manufacturer: _____
- Model/Type: _____
- Generated Voltages: _____ V Generated Frequencies: _____ Hz
- Rated kVA: _____ Rated kW: _____
- Rated Currents: _____ A Efficiency Factor: _____
- Winding Connection (D/W/GW): _____ Power Factor: _____

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: _____
- Measured Voltages: _____ V Measured Temperatures: _____ °F

Generator Set #2

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair
❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: _____

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: _____
- Model/Type: _____ Rated Voltage: _____
- Rated hp (or kW): _____ Rated Current: _____
- Power Factor: _____ Frequency: _____

Generator Data:

- Manufacturer: _____
- Model/Type: _____
- Generated Voltages: _____ V Generated Frequencies: _____ Hz
- Rated kVA: _____ Rated kW: _____
- Rated Currents: _____ A Efficiency Factor: _____
- Winding Connection (D/W/GW): _____ Power Factor: _____

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: _____
- Measured Voltages: _____ V Measured Temperatures: _____ °F

Courtesy of U.S. Army Corps of Engineers NFPA 70B (p. 1 of 2)

GENERATOR SET SURVEY *(continued)*

Generator Set #3

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair ❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other:_____

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer:_____
- Model/Type: _____ Rated Voltage:_____
- Rated hp (or kW): _____ Rated Current:_____
- Power Factor:_____ Frequency:_____

Generator Data:

- Manufacturer:_____
- Model/Type:_____
- Generated Voltages: _____V Generated Frequencies: _____Hz
- Rated kVA: _____ Rated kW: _____
- Rated Currents:_____A Efficiency Factor: _____
- Winding Connection (D/W/GW):_____ Power Factor: _____

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: _____
- Measured Voltages:_____V Measured Temperatures:_____ °F

Generator Operation:

- Can these generators run in parallel with the utility power sources? ❑ Yes ❑ No
- The generators are being used as: ❑ Backup source ❑ Peak shaving ❑ Prime source
- Are the generators properly protected against overload? ❑ Yes ❑ No abnormal conditions? ❑ Yes ❑ No or reverse power flow (if generators can run in parallel with utility source)? ❑ Yes ❑ No
- Can the generators automatically start? ❑ Yes ❑ No and automatically shut off? ❑ Yes ❑ No
- How many times did generator fail to start or break down (with unknown reason) during the last few years?_____

Maintenance:

- Does the generator operation log book exist and is it up to date? ❑ Yes ❑ No
- How often does the generator run for maintenance? _____times per week/month, ❑ with loads or ❑ without loads.
- How long did the generator run during each maintenance period? _____ minutes
- How often is the generator fuel system checked? _____times per week/month

Generator Grounding System:

- ❑ Solidly grounded ❑ High resistance ❑ Low resistance ❑ Reactance
- Measured ground impedance in ohms:_____
- Is the generator's neutral bus connected to ground? ❑ Yes ❑ No
- Is the generator frame connected to ground? ❑ Yes ❑ No

Notes:

_____

_____

_____

_____

_____

Courtesy of U.S. Army Corps of Engineers

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Figure 3-3 Generator Data Record

GENERATOR DATA RECORD

Site: _____ Date: _____ Page: _____

No.	Location	Type	kVA Rating	Generated Volts	Rated Current	Speed in RPM	Wiring Connections	Subtrans. Impedance	Ground Impedance	Power Factor

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3-5.7 Spare Parts Lists.

Identify high-rate-of-mortality parts by historical experience. Ensure spare parts for each system of the generator is available for use when there is a need for replacement. Refer to the spare parts lists provided by the equipment manufacturer.

3-5.8 Service Contract Documents.

Describe typical service contract types and contract documents necessary to manage the service contract program if a service contract is utilized.

CHAPTER 4 OPERATIONS

4-1 OPERATING PROCEDURES.

4-1.1 Responsibilities.

There are levels of approval required for **any** changes to occur to generators. Know the changes, who/what it impacts, and obtain appropriate approvals before executing.

Know and ask advice from the appropriate SME.

\1\ Note: The Air Force will follow operations, maintenance, and testing requirements in Chapter 8. **/1/**

4-1.2 Fire Emergency.

Train operators on fire safety procedures. In fire emergencies, call the fire department and identify the specific fire emergency area.

4-2 AIR QUALITY PERMITTING.

Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*, and agency-specific environmental regulations, restrictions, and specific applicable environmental guidance. In addition to the listed permitting activities herein, contact state and local environmental and development offices to verify additional permitting requirements. Maintainer/operator must coordinate with the local environmental office to ensure continued compliance with operating permits, especially when changes occur.

Obtain and maintain all required air permitting in accordance with the rules of the Clean Air Act (CAA) regulatory agency (federal or state/local/tribal) with delegated authority over the location of subject operations.

\1 [Note deleted] **/1/**

4-2.1 New Permits and Modifications to Existing Permits.

Initial permitting activities are accomplished during the design phase and prior to equipment installation. When changes are made to a unit (e.g., modified, remanufactured, relocated, and/or how it is used/operated), operators will immediately notify the appropriate environmental management office(s) that hold existing permit(s) of these changes and provide them with the necessary system information required to update those permits. This is necessary to ensure continued compliance with applicable federal, state, and local laws.

4-2.2 Changes.

Operational permitting is done during design and installation. Existing standby generators require additional permitting when operating hours exceed the permit. However, when changes are made to the unit or how it is used, the operators will

immediately notify their office(s) that holds the existing operating permit(s) of these changes and provide them with the necessary system information required to update the operating permits. This will ensure continued compliance with applicable federal, state, and local laws.

4-3 COMPLIANCE MONITORING AND INSPECTIONS.

4-3.1 OSHA Compliance and Monitoring.

The generator must comply with the requirements and regulations of OSHA for personnel safety, including safe work practices.

4-3.2 Air Quality Compliance.

Generator engines must meet and maintain compliance with the requirements of federal, state, and local regulations and facility-specific permits. Air quality regulations/permits may specify monitoring, recordkeeping, and reporting requirements, as well as O&M frequencies/practices.

\1\ Note: The Air Force will follow operations, maintenance, and testing requirements in Chapter 8. **/1/**

4-3.3 Clean Water Act (CWA) Compliance and Monitoring.

Generators must comply with CWA regulations to prevent the spill of oil, petroleum, or other contaminants to the water.

4-3.4 Resource Conservation and Recovery Act (RCRA) Compliance Monitoring.

Generators are required by RCRA to properly control and manage hazardous waste.

CHAPTER 5 RELIABILITY MAINTENANCE-CENTERED PRACTICES

5-1 PURPOSE AND SCOPE.

This chapter provides guidance on typical preventive maintenance practices to keep generators in good performance.

5-2 PREVENTIVE MAINTENANCE ELEMENTS (TIME-BASED).

5-2.1 General.

Refer to manufacturers' manuals for maintenance and repair requirements, frequencies, and consumables specifications. On standby generators in locations without SCADA or communications links, the self-test alarm is not monitored. For these applications, or applications where there are no self-diagnostics on the relays, the relays should be tested every one to six years. The timespan is based upon the relay installation, atmosphere, debris, temperature, and humidity.

5-2.2 Load Bank Optimization.

Load banks are used for load optimization, allowing the generator to run at a higher load than needed for facility power to prevent engine damage to certain types of prime movers. Use load banks to augment facility load to optimize generator performance when the prime mover is operating at less than the manufacturer's minimum rated load for continuous operation.

5-2.3 Prime Mover (Engines).

Prime mover preventive maintenance activities are mandatory. These activities are required to ensure the prime mover reaches their expected life expectancy as they are an expensive and essential part of the generator set. Maintenance activities include the following:

5-2.3.1 Structures and Enclosures.

Check structures and enclosures for corrosion. For corroded areas, clean, prepare and apply corrosion-control treatment on affected surfaces to avoid further deterioration.

5-2.3.2 Power Takeoff Assemblies and Couplings.

Check for coupling alignment in accordance with manufacturer's maintenance schedule.

5-2.3.3 Bearing Lubrication.

Inspect and ensure the proper amount of grease on bearings and replace as required by the maintenance schedule.

5-2.3.4 Belt-Driven Equipment Checks.

Check misalignments on belt-driven equipment. Replace belts if damaged, as required.

5-2.4 Cooling System.

Dust can foul cooling passages, increase operating temperature, and negatively affect the generator's/engine's performance. Clean radiators of dust and debris. Use soft brush or cloth. Avoid damaging the fins. Use low-pressure air or water in the reverse direction from normal flow to clean the radiator.

5-2.4.1 Coolant Levels.

- Check the coolant levels during shutdown periods. Premix the coolant in a clean tank when replacing the coolant to an engine.
- Never add antifreeze directly into the engine cooling system.
- Avoid adding coolant to an overheated engine.
- Avoid adding coolant at a rate of more than 10 gallons per minute when filling and emptying the engine cooling system.
- Check heat exchangers. Poor coolant maintenance can result in heat exchanger damage.

5-2.4.2 Coolant.

Engines with wet liners are subject to liner pitting and pumps/seals are subject to failure if the cooling system is not properly maintained**.** Use the coolant recommended by the engine manufacturer.

The following are unacceptable coolant maintenance practices:

- Use of non-treated (distilled or de-ionized) water.
- Use of water alone as coolant.
- High or low concentrations of supplemental coolant additive (SCA).
- Use of anti-freeze or SCA that are high in silicates or do not meet original equipment manufacturer (OEM) specifications.
- Topping off coolant system without proper SCA.

5-2.4.3 Coolant Maintenance.

Perform the following coolant maintenance:

- Test the coolant a minimum of twice a year for freeze protection, coolant/water percentages, nitrite or SCA level, pH, visual color and appearance, and reserve alkalinity. Use a spectro-chemical test with results reported in parts per million (ppm) and SCA.
- Drain and replace coolant at intervals in accordance with the engine and/or coolant manufacturer's recommendation or when coolant analysis dictates replacement.

- When topping off, add coolant until the level is at the radiator cap's lower sealing surface.
- Store coolants out of direct sunlight and replace when shelf life has expired.

5-2.4.4 Air Intake/Ventilation Systems.

- Check for obstructions to cooling air lines or paths.
- Check for deterioration of cooling air ducts. This deterioration can lead to leakage of airflow, reducing its capacity.
- Check for dust and dirt of cooling air ducts.
- Check for loose or misaligned airline connections.

5-2.4.5 Coolant Pumps.

Inspect and maintain coolant pumps in accordance with maintenance schedule.

5-2.4.6 Engine Water Jacket Heaters.

Inspect engine water jacket heaters while in operation and observe for leaks at hoses, adapters, cylinder heads, pump seals, and block seals. Check for engine water jacket heater damage or deterioration. Inspect and maintain jacket water heaters in accordance with manufacturer's recommendations.

5-2.4.7 Valve Exercising.

- Verify correct position/alignment on valves.
- Check for leaking seals.
- Verify correct operation of valves.

5-2.4.8 Safety Relief Valve Tests.

- Check for leaks on safety relief valves and replace if leaks continue.
- Check that the safety relief discharge piping is working properly.
- Check that the safety relief valve opens at the acceptable pressure value.
- If the safety relief valve opens at a pressure below the acceptable range, it may indicate that the relief valve is in a deteriorated condition and requires replacement.
- If the safety relief remains closed, do not operate the system until the safety relief valve is completely replaced.

5-2.5 Lubrication System.

Maintain lubrication systems to comply with applicable standards and specifications.

5-2.5.1 Oil Level.

Ensure generator oil levels comply with the indications presented on the manufacturer's instruction manuals to keep the generator in good performance. Test the oil quality to determine oil level, conditioning, or replacement. For accurate readings on the dipstick, wait at least 10 minutes after shutting off the engine to allow the oil to drain to the bottom.

5-2.5.2 Oil Change.

- Replace oil according to the recommendations given by the manufacturer.
- Drain oil while warm.
- Test a sample of the drained oil to examine for fuel dilution, acidity, and the presence of solids and contaminants.
- Ensure oil change frequency is in accordance with manufacturer and environmental air quality regulatory requirements.

5-2.5.3 Oil Filter Change.

\1 Inspect oil filters periodically and replace when an accumulation of sludge or other contaminants is present. **/1/** The frequency is shown in Table 6.1.

5-2.5.4 Crankcase Breather.

Check crankcase breather each time the generator is taken down for maintenance to make sure it is not clogged and unusable.

5-2.5.5 Oil Leaks.

Check for oil leaks and follow the instructions of the manufacturer if oil leaks are found.

5-2.5.6 Gauges and Safety Mechanisms.

During maintenance, observe gauges and safety mechanisms and check fuel and temperature gauges to ensure proper operation.

5-2.6 Fuel System (Including Long-Term Fuel Storage).

Inspect and clean fuel systems. Remove contaminants such as dirt and sediments from tanks storing fuel to ensure proper engine operation. Test and analyze a sample of fuel taken from the storage tank to check for the presence of contaminants. One of these samples must include one sample taken from the inside bottom of the tank.

Note: For the Air Force, fuel testing should be coordinated with the Logistics Readiness Squadron (LRS) POL Fuels Lab.

5-2.6.1 Fuel Additives.

Check the proper levels of fuel additives in the system.

5-2.6.2 Fuel Filters.

Inspect and clean fuel filters as recommended by the manufacturer for identifying contaminants, sediments, or microorganisms.

5-2.6.3 Water/Condensate Removal.

Sample fuel from the fuel tank to detect the presence of water. Fuel and water tend to separate and water will sink to the bottom of the container. Remove water accumulation from storage fuel tanks with the provision and use of drain valves.

5-2.6.4 Fuel System Components.

Check fuel oil components such as fuel hoses, fuel pipes, fuel filters, injector pumps, etc. If damage to these components is encountered, replace following the instructions provided by the manufacturer. Make sure the lines are not rubbing against anything that could cause an eventual failure. Immediately repair any leaks or alter line routing to eliminate wear.

5-2.6.5 Gauges and Safety Mechanisms.

Check for accuracy on fuel level gauges and repair gauges as required.

5-2.6.6 Fuel Pumps.

Fuel pumps must be maintained to deliver sufficient fuel and sustain a satisfactory combustion to operate the generator. Fuel pumps must be cleaned by removing contaminants such as dirt, sand, and water.

5-2.6.7 Fuel Storage Tank Maintenance.

Clean and inspect fuel storage tanks every 10 years in accordance with API Standard 2015, *Requirements for Safe Entry and Cleaning of Petroleum Tanks*.

Drain tanks of water monthly to minimize corrosion of the inner tank surface. Bacterial growth in diesel fuel will be a problem in warm areas. **\1** Test fuel for contamination and polish as required if fuel is not used within three months. **/1/**

\1 [Note deleted.] **/1/**

5-2.7 Air Intake Systems.

5-2.7.1 Air Filters.

Prior to removing the intake air filters, remove accumulations of dirt from the air filter housing. Remove air filters and wipe to remove excess dust and dirt. Replace intake air filters per recommendations of the manufacturer.

5-2.7.2 Unlined Expansion Joints.

Inspect unlined expansion joint belts for cuts, worn sections, and cracks. Replace belts that are excessively worn and have cracks. Repair or replace belts with cuts per manufacturer's instructions. Inspect backing bars, mating flanges and hardware for corrosion. Refer to manufacturer's instructions for corrosion repair. Check fastener torque and re-torque to manufacturer's recommendations, as appropriate.

5-2.7.3 Unlined Duct.

Clean duct and check for corrosion and signs of water and air leakage. For paint, corrosion repair, and gasket replacement, refer to manufacturer's instructions.

5-2.7.4 Silencer Duct.

Clean duct and check for corrosion and signs of water and air leakage. For paint, corrosion repair, and gasket replacement, refer to manufacturer instructions.

Check acoustic insulation lining for water damage, corrosion, and cracking. For repair, refer to manufacturer's instructions.

5-2.7.5 Acoustically Lined Duct.

Clean duct and check for corrosion and signs of water and air leakage. For paint, corrosion repair, and gasket replacement, refer to manufacturer's instructions. Check acoustic insulation lining for water damage, corrosion, and cracking. Check access hatches and maintenance ports for air-tight seals. For repair, refer to manufacturer's instructions.

5-2.7.6 Trash Screens.

Inspect screen and framework for damage, including broken wires and missing screens. Replace damaged screens and tighten loose wires. Check screen frame and screen holder for corrosion. For repair, refer to manufacturer's instructions.

Check screen for deflection using hand pressure. If deflection is greater than 4 inches (100 mm), replace screen.

5-2.7.7 Expansion Joints.

Inspect expansion joint belts for cuts, worn sections, and cracks. Replace belts that are excessively worn and have cracks. Check manufacturer's repair instructions for cracked belts as this typically indicates a system malfunction or alignment problem. Repair or replace belts with cuts per manufacturer's instructions.

Inspect backing bars, mating flanges, and hardware for corrosion. Refer to manufacturer's instructions for corrosion repair. Check fastener torque and re-torque to manufacturer's recommendations, as appropriate.

5-2.7.8 Inlet Plenum and Cone.

Inspect and repair inlet plenum per manufacturer's instructions.

5-2.8 Exhaust System.

Exhaust systems need to be maintained to keep the generator in good performance. Check for leaks at all connections, welds, gaskets, and joints. Make sure the exhaust systems are not heating the surrounding areas more than normal. Check for excessive smoke upon starting; this indicates air quality problems.

5-2.8.1 Air Induction Piping.

Exhaust system piping of generators must have suitable devices to prevent the entry of water from rain.

5-2.8.2 Turbochargers and Blowers.

Clean and maintain turbochargers in accordance with manufacturer's recommendations.

5-2.8.3 Exhaust Manifolds.

Check exhaust manifolds for rust and corrosion.

5-2.8.4 Emissions System and Controls.

Maintain emissions system controls (e.g., catalytic oxidizers, exhaust particulate filters) and monitoring devices (e.g., continuous emissions monitoring systems) in accordance with manufacturer's and environmental regulations/requirements. Manufacturer's instructions should be consulted for procedures specific to each model. Contact the environmental compliance office when problems are identified.

5-2.9 Generator Components.

Accomplish generator inspection, maintenance, and service in accordance with manufacturer's requirements, environmental regulations/requirements, and/or recommendations or applicable technical orders. Listen and look for changes in

performance or sound. Misfires and changes in oil consumption indicate service will be required.

There may be regulatory maintenance and maintenance recordkeeping requirements that vary greatly from engine to engine, according to whether the engine is:

- New or existing
- Located at an area source or major source of hazardous air pollutant (HAP) emissions
- A compression ignition or a spark ignition engine; include requirements associated with 40 CFR Part 63 Subpart ZZZZ, 40 CFR Part 60 Subpart JJJJ, and 40 CFR Part 60 Subpart IIII

5-2.9.1 Stator and Rotor Windings.

Clean stator and inspect the following items:

- Check coil ends for distortion or movement.
- Check damaged, missing, or broken wedges. Wedges that have lifted in the dovetail or have been burned must be replaced.
- **\1** Open, check, and clean cooling passages. **/1/**
- Check security of lashing and spacers.
- Check tightness of coil supports.
- Check partial discharge activity and other damages to coil insulation, including end windings and in the slot.
- Check connections between coils.
- Measure insulation resistance between winding and ground at the machine terminals.

Clean rotor and inspect the following items:

- Check clearance between blower and coils.
- Check damper winding for loose bars.
- Check proper connection between each bar and its ring segment.
- Check connections between field coils and collector rings.
- Check field coils for separation or movement.
- Clean oil and dirt from air passages and winding.
- Measure resistance between field coils.
- Check damaged bearings and journals.
- Check for insulation damages.

- Measure vibration limits at starting.

Refer to manufacturer's manuals for instructions on stator and rotor maintenance and repairs, and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.2 Brushes.

Typical preventive maintenance practices on brushes are the following:

- Check brush faces for heat cracks and replace if damaged.
- Check for loose brush studs.
- Check brush shunts to ensure they are properly secured to the brushes and holders.
- Check that the brushes are resting at the correct angle and in the neutral plane.
- Ensure brushes are properly spaced on the commutator and brush holders are properly spaced from the commutator.

Refer to manufacturer's manuals for instructions on brush maintenance and repairs, and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.3 Collector Rings.

Typical preventive maintenance practices on collector rings are the following:

- Clean collector rings using a solvent cleaner and a stiff brush.
- Check insulation resistance between ring and shaft for defective bushings and collars.
- Check brush holder endplay to prevent grooving of collector rings.

Refer to manufacturer's manuals for instructions on collector rings maintenance and repairs, and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.4 Commutators.

Typical preventive maintenance practices on commutators are the following:

- Check commutator surface for grooving, scratches, or roughness.
- Check commutator concentricity with a dial gauge.
- Remove every trace of carbon, copper, or dust when the commutators are being cleaned.

Refer to manufacturer's manuals for instructions on commutators maintenance and repairs, and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.5 Sleeve Bearings.

Typical preventive maintenance practices on sleeve bearings are the following:

- For old sleeve bearing types, the oil needs to be replaced at least every year.
- Check the oil level for new sleeve bearing types.
- Check that bearing insulation is not short-circuited by bearing temperature detectors or by lubricating oil piping. Bearing insulation is important to eliminate bearing circulating currents, preventing pitting of the shaft and bearing.

Refer to manufacturer's manuals for instructions on commutators maintenance and repairs and frequencies. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.6 Ball and Roller Bearings.

Typical preventive maintenance practices on ball and roller bearings are the following:

- The bearing housing and bearing itself should be greased. Check the condition of the bearings and grease. Clean and add grease as needed.
- Follow manufacturer's manuals for recommendations regarding the type and quantity of lubricant/grease to be applied. Note that the intent is to follow manufacturer's instructions. Small units call for a much less stringent set of inspections.

5-2.9.7 Insulation Structures.

Typical preventive maintenance practices on insulation structures are the following:

- All insulation structures clogged with mud from weather events must be washed with pressure water not exceeding 25 psi (172.4 kPa), unless otherwise noted on the manufacturer's instruction manual.
- Dry all electrical insulations at 185 °F (85 °C) for four hours, followed by 225 °F (105 °C) to 248 °F (120 °C) for another four hours, unless otherwise noted on the manufacturer's instruction manual.
- After drying, measure winding insulation resistance with an insulation test instrument. The measurements must be in accordance with the insulation levels presented in IEEE 43, *IEEE Recommended Practice for Testing Insulation Resistance of Electric Machinery*.

5-2.10 DC Electrical System.

Check circuit breakers and exercise breakers. Check wiring for loose connections and perform an insulation test of all wiring.

5-2.10.1 Battery Electrolyte Level/Specific Gravity.

Typical preventive maintenance practices on insulation structures are the following:

- Inspect storage batteries, including electrolyte levels, every week and maintain by following the manufacturer's instructions.
- Check electrolyte levels before water is added by following the manufacturer's recommendations. Excessive water consumption can be an indication of overcharging, cell damage, or aging.
- Test and record monthly the lead-acid battery electrolyte specific gravity.
- Perform battery discharge tests a maximum of twice a year. This is also called load testing or capacity testing in some locations.

5-2.10.2 Battery Compartment.

- Inspect battery compartment damage as a result of vibration.
- If vibration is observed, isolate the batteries from vibration by following the manufacturer's prescribed procedures.

5-2.10.3 Battery Connections.

- Check battery interconnections for tight connections and corrosion.
- Clean and torque battery terminal connections.

5-2.10.4 Battery Charging System.

- Verify battery chargers' output voltage minimum of once per month.
- Check battery charger cable interconnections and cell connectors.
- Check for dirt, wear, and corrosion.
- Maintain battery chargers following the manufacturer's recommendations.

5-2.11 AC Electrical System.

Check relays and cable as scheduled and perform cable testing on medium-voltage cables every three years.

5-2.11.1 Voltage Regulator.

Follow manufacturer's instructions for maintenance of voltage regulators.

5-2.11.2 Control Panel.

Open up the control panels, look for corrosion, and dust, and perform an infrared (IR) scan of the inner equipment. Clean where necessary. Ensure the control system is logging data (where required).

5-2.11.3 Switchgear.

- Check for switchgear conditions causing carbon tracks.
- Check for damaged barriers and shutters.
- Perform insulation resistance tests (phase-phase [p-p] and phase-ground [p-grnd]) with the use of a megohmmeter.
- Check for discoloration of circuit breaker conductors, indicating overheating.
- Test circuit breaker contacts for opening and closing sequences.
- Test for alarm condition activation of switchgear alarms (if equipped).
- Consult manufacturer's recommendations.

5-2.11.4 Automatic Transfer Switches (ATS).

Perform the following monthly, according to NFPA 110:

- Inspect, operate and lubricate mechanical linkages.
- Verify mechanical interlocks operation.
- Test switch performance and operation by manually initiating transfers in both directions.
- Verify correct indication light operation.

Consult manufacturer's recommendations.

5-3 PREDICTIVE MAINTENANCE ELEMENTS (CONDITION-BASED).

5-3.1 General.

Refer to manufacturers' manuals for maintenance and repair requirements, frequencies, and consumables specifications.

Note: The Air Force will follow requirements in Chapter 8.

5-3.1.1 Visual Inspections.

Perform visual inspections for every generator system as indicated in Figures 3-1 and 3-2.

5-3.1.2 Application and Scanning.

- Electrical and mechanical systems
- Electrical components
- Corrosion damage

5-3.2 Electrical and Mechanical Systems.

5-3.2.1 Electrical Components.

All switchgear, transformer connections, switchgear connections and panelboards should be IR scanned on a programmed basis based on available resources.

5-3.2.2 Corrosion Damage.

Remove any corrosion damage to base metal. Prime and paint with the same paint originally recommended by the manufacturer.

5-4 GENERATOR LOAD TESTING.

When load testing, use facility loads first and load banks as secondary loads only. Load banks should only be used when facility loads are insufficient to bring the generator to the required level of load/temperature.

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CHAPTER 6 TYPICAL INSPECTION AND MAINTENANCE SCHEDULES

6-1 PURPOSE AND SCOPE.

Follow manufacturer's maintenance schedules, as modified by generator loading.

6-2 PREVENTIVE MAINTENANCE (PM) SCHEDULES.

See Table A-1 for sample PM schedule.

6-3 PREDICTIVE MAINTENANCE SCHEDULES.

Provide typical predictive inspection and maintenance schedules and guidance—broken down by hourly, daily, weekly, monthly, and annually—for generator systems and components in table format (refer to Table 6.1 as an example). Review EPA regulations to ensure EPA-required O&M frequencies/practices for key systems have been incorporated into inspection and maintenance. Ensure requirements in 40 CFR Part 63 Subpart ZZZZ, 40 CFR Part 60 Subpart JJJJ, 40 CFR Part 60 Subpart IIII, and 40 CFR Part 89 are not violated (when applicable, based on generator age and location).

Emergency power supply systems (EPSS) should follow the maintenance schedule described in Annex A of NFPA 110 and Figure A.8.3.1(a) of that Annex.

Table 6-1 Typical Generator Maintenance Schedule

	Service Time		
Maintenance Items	**Monthly**	**6 Months**	**Yearly**
Visual inspection	X		
Check coolant heater	X		
Check coolant level	X		
Check oil level	X		
Check fuel level	X		
Check charge-air piping	X		
Check/clean air cleaner	X		
Check battery charger	X		
Drain fuel filter	X		
Drain water from fuel tank	X		
Check coolant concentration	X		
Check drive belt tension	X		
Drain exhaust condensate	X		
Check starting batteries	X		
Change oil and filter		X	
Change coolant filter		X	
Clean crankcase breather		X	
Check radiator hoses		X	
Change fuel filters		X	
Clean cooling systems			X

CHAPTER 7 PRIME POWER

7-1 GENERAL REQUIREMENTS.

The maintenance of the generator includes all associated generator systems, including cables, prime movers, and ancillary equipment. This chapter covers additional prime power considerations in addition to the requirements of the previous chapters.

7-2 CERTIFICATION OF GENERATOR WORKERS.

Turbine generator and power plant operators must have a valid power engineer's license or DoD plant operator license issued by the National Institute for the Uniform Licensing of Power Engineers, Inc. (NIULPE) (http://www.niulpe.org/certification.shtml) or an approved internationally recognized third-party certification agency. This licensing is only required for a power plant connected to the grid and **not** standby generators.

7-3 COMBUSTION TURBINE ENGINE.

Combustion turbine engines use a jet engine to burn fuel with the exhaust gases rotating a turbine generator. The major components of combustion turbine engine requiring maintenance typically include:

- Air intakes
- Compressors
- Combustors
- Turbines
- Afterburners
- Nozzles
- Cooling system
- Fuel system
- Starting system
- Ignition system
- Lubrication system
- Control system

7-4 GASEOUS FUELS.

Gaseous fuel systems components requiring maintenance include:

- Storage system (if not direct utility provided)
- Regulating stations and relief devices
- Automatic shutoff devices

- Coalescing filters
- Gas fuel heating system
- Gas fuel scrubber
- Corrosion control system

7-5 FUEL OIL.

Fuel oil system components that typically require maintenance include:

- A fuel receiving station(s) from either a truck, train, ship, or pipeline, or combination thereof
- Bulk storage system (above ground and below ground)
- Day tanks
- Transfer pumps
- Fuel maintenance (filtration) system
- Fuel coolers
- Supply and return piping system
- Corrosion control system
- Leak detection systems
- Control system

7-6 LUBRICATING SYSTEMS – GAS TURBINE ENGINES.

The typical components for a gas turbine engine requiring maintenance include:

- Tanks
- Pressure pumps
- Scavenger pumps
- Filters
- Oil coolers
- Relief valves
- Breathers and pressurizing components
- Pressure gauges and instrumentation
- Temperature regulating valves
- Oil-jet nozzles
- Magnetic chip detectors
- Tubing, hose, and fittings

7-6.1 Oil Analysis.

Test generator oil on a recurring maintenance schedule. General and physical tests are suggested twice a year.

7-6.1.1 Oil Sampling Technique.

Oil sampling in generator engines should be taken at the following sampling points and sealed:

- Through dipstick holder
- Sample valve on crankcase sump wall
- Return line before filter

7-6.1.2 Chemical and Physical Testing.

Perform chemical and physical testing for every generator system as specified in Figure 3-1.

7-6.2 Ultrasonic Scanning.

Check if weld leaks are detected in the lines or corrosive liquids are carried through the lines. Perform this validation at least once every five years.

Scanning welds requires a high level of operator training. It is recommended a third party be contracted to perform these inspections if in-house expertise is not available.

7-6.3 Weld Inspection.

Physically inspect welds to verify no cracks or corrosion are occurring on the welds for piping not ultrasonically tested. These should be examined every five years.

7-6.3.1 Instrumentation, Transducers, and Transformers.

Ensure calibration cycles are:

- As recommended by the manufacturer of the instrument;
- One year for electrical, electronic and mechanical test equipment or three years for mechanical test equipment made of solid materials not subject to deterioration.

Calibration intervals may be extended based on the following conditions and the reasons must be documented:

- Passive electrical test equipment, such as current shunts, current transformers, and potential transformers, may be extended to three years with good results for the initial calibration period and if not subject to severe-use conditions.

- Where there is sufficient calibration data to statistically establish a trend of the test equipment to assure good measurement results for a longer period.

7-6.3.2 Scanning Analysis.

After the test data is gathered, this data should be compared to earlier testing data to determine any changes. Data showing corrosion or high resistances must be addressed.

7-6.3.3 Application and Technique.

Items to look for when analyzing data include:

7-6.3.3.1 Applications.

- Surface breaking cracks
- Metal thinning
- Tube inspection
- Conductivity
- Thickness

7-6.3.3.2 Scanning.

- Multi-frequency
- Swept frequency
- Pulsed
- Remote field
- Impedance matching

7-6.3.4 Equipment and Probes.

The equipment for scanning is called a multi-frequency probe. It is hand-held, with ultrasonic scanner diagnostics. Other probes, such as pulsed and impedance matching, remote field, etc., can be found from the same manufacturers that produce other ultra-frequency scanners.

7-6.3.5 Inspection Analysis.

Inspection analysis can usually be gathered directly from the scanner or it can be available through a software application with input from the scanner.

7-6.4 Steam Turbine System.

There are two main types of steam turbines: superheated steam and saturated steam. In a saturated steam turbine, the increased moisture in the steam path accelerates blade erosion, diminishes efficiency, and requires a water removal system in the saturated steam inlet lines. The more complex saturated steam systems have increased maintenance requirements.

7-7 PRIME COOLING SYSTEMS.

7-7.1 Stator Cooling Systems.

On very large units (over 40 MW), there may be a stator cooling system. The stator cooling system maintains the stator bars and screen plates within operating temperature range using demineralized cooling water. Ensure the system operates at a pressure lower than the hydrogen seal pressure, filters particulates that can plug or damage the stator tubes, and the demineralized make-up water system provides required make-up water due to loss or leaks. Also, ensure the leak detection system is operating within the manufacturer's operating parameters and venting to atmosphere is provided for over-pressure of hydrogen gas.

Ensure the generator hydrogen seal oil system operates under all conditions and maintains the seal oil at correct operating temperatures and differential pressure.

7-7.1.1 Stator Water Cooling System.

Stator water cooling system components typically requiring maintenance include:

- Demineralized water system
- Pumps
- Emergency pump
- Water cooler
- De-oxygenating unit
- Strainer
- Resistance columns
- Gas detraining chamber

7-7.1.2 Stator Hydrogen Cooling System.

Hydrogen cooling system components typically requiring maintenance include:

- Gas supplies
- Hydrogen dryer
- Hydrogen gas analyzer

- Centrifugal fans
- Hydrogen coolers
- Seal oil pumps (AC and DC)
- Seal oil pump pressure control valve
- Seal oil loop seal
- Seal oil cooler
- Filters
- Detraining chamber
- Gas trap
- Bearing seals
- Hydrogen dryer
- Air scavenging
- Purity monitor
- Stator coolant system (strainers, demineralization plant, flow measurement instrumentation, gas alarm and automatic release chamber, and gas detraining chamber)

7-8 INTAKE AIR MAINTENANCE.

7-8.1 Gas Turbine Intake Air.

For gas turbine engines, the consequences of poor inlet filtration are more significant with foreign object damage, erosion, fouling, particle fusion, or corrosion of the compressor fans. As such, gas turbine air filtration systems typically use multiple stages of weather protection, inertial separators, pre-filters, coalescers, and final filters.

7-9 SPECIALTY TOOLS AND EQUIPMENT.

Consider acquiring and using the following specialty tools and equipment:

- Lube oil flush system
- Coolant flush system
- Valve and bearing inspection tools
- Exhaust analyzer
- Remote racking mechanisms for switchgear circuit breakers (Several manufacturers provide remote racking mechanisms that allow the electrical worker to stay well outside the arc flash boundary during circuit breaker racking operation.)

- Remote switching actuators for circuit breakers (Enables remote circuit breaker operation [open or close].)
- Thermal imaging cameras
- Power quality data loggers (For evaluating normal system parameters, such as voltage, current, power factor and harmonic distortion, as well as evaluating abnormal events, such as voltage swells, sags, or outages.)
- Wet/dry hot stick tester
- Fault locating equipment

7-10 TOOL SAFETY

7-10.1 Energized Lines.

The methods used when working on energized lines, such as gloving, use of hot line tools, and provision of electrically insulated buckets, will be in accordance with the applicable services' safety manuals. Safety rules governing the use of such tools and equipment are given in these manuals and in applicable OSHA regulations, 29 CFR 1910 and 29 CFR 1926.

7-10.1.1 Climbing Equipment.

When generators/equipment are over 6 feet (1.8 meters) in height, climbing equipment must be used if there are no permanent ladders and walkways. Climbing equipment includes body belts, safety and climber straps, climbers, and ladders. Refer to 29 CFR 1926.501 for OSHA details. Use personal fall arrest systems in accordance with 29 CFR 1910.269(g)(2)(iv)(B) and 1926.502(d).

7-10.2 Insulating Hydraulic Fluid.

An insulating-type hydraulic fluid is required in all hydraulic hand tools used on or near energized lines and in insulated sections of aerial lift trucks. Hazardous material procedures must be followed when dealing with such substances.

7-11 POWR PLANT OPERATIONS.

7-11.1 Load Shedding.

Load shedding should be the deliberate and selective dropping of electrical load in accordance with a preplanned program specific to a base. There must be a plan to load-shed circuits that minimizes impact to critical loads.

7-11.2 Methods of Load Shedding.

To have proper load shedding, a prioritized load-shedding program must be established and implemented. This scenario arises most often when loads are added after the initial installation. The criteria for load shedding are primarily frequency based, and must

occur when the frequency drops below 56.6 Hz for diesel reciprocating units and 58 Hz for turbines.

7-11.3 Requirements for Load Reduction.

A scenario could involve an isolated plant (not interconnected with a utility), with several generating units loaded at or near their combined capability. Should one unit trip, the remaining units would experience a sudden load increase, possibly leading to loss of the plant.

7-11.4 Total Load Reduction.

The load-shedding plan must accomplish a total load reduction sufficient to relieve the plant overload and provide a slight underload so the plant will have reserve capacity to reaccelerate to the normal operating frequency. One must also consider the loss of capacity that results from under-frequency operation.

7-11.5 Methods of Load Shedding.

There are many methods of load shedding, both automatic and manual. The automatic methods include under-frequency relaying and various transfer-trip arrangements. All of these methods have relative advantages and disadvantages and the choice of the most advantageous method should be based on the specific conditions that prevail. However, load shedding by under-frequency relaying is the most common and generally the preferred method.

7-11.6 Electrical Usage and Criticality.

In general, the least-critical loads should be tripped first and the load-shedding should proceed in stages, with progressively more critical loads being shed at each stage. The following provides guidelines for the determination of the relative criticality of loads.

7-11.6.1 Critical Loads.

To develop a load-shedding plan, identify the critical loads first along with an estimate of the magnitude of each. Design the load-shedding plan so the critical loads are shed last. In some cases, it may be necessary to divide the critical loads into two or more categories and assign relative priorities to each category.

7-11.6.2 Mission-Critical Loads.

Mission-critical loads are loads essential for the operation of the facility and broader agency mission support. If these loads are shed, they would adversely affect the facility mission, national security, critical communications, the warfighting mission, or base security.

7-11.6.3 Life Support Loads.

Life support loads include hospitals and similar high-occupancy facilities where loss of power may endanger life.

7-11.6.4 Time-Critical Loads.

In many cases, load criticality will vary with time. Take time variations into account when designing the load-shedding plan.

7-11.6.5 Seasonal Variations.

In a severely cold climate, a load related to providing heat could be considered critical during the winter and noncritical during the summer. Under the same conditions, the power supply to a frozen food storage facility could be considered critical during the summer and non-critical during the winter.

7-11.6.6 Diurnal Variations.

The criticality of some loads may vary from day to night or from weekday to weekend because of changing usage. Examples may include auditoriums, theaters, and offices.

7-11.6.7 Interruptible Loads.

Some loads can withstand short interruptions but not lengthy interruptions. Examples may include community facilities with emergency (battery-powered) lighting. These loads can be classified non-critical for load shedding but could also be given a high priority for load restoration.

7-11.7 Stable Operation and Overload Capability.

Generating plants are highly sensitive to frequency drop. There are two major problem areas: motor speed and turbine blade fatigue.

7-11.7.1 Operating to Avoid Turbine Blade Fatigue.

The last rows of long, low-pressure blades in steam turbines are tuned to operate free of resonance in a narrow band of frequencies around 60 Hz. When running under heavy load at about 58.5 Hz or below, the steam excitation frequency approaches blade resonance. Under this condition, the blades may vibrate severely, producing fatigue stress. On average, blades should not be subjected to more than ten minutes of severe vibration total over their lifespan, as fatigue is cumulative. Operation below about 58.0 to 58.5 Hz should be avoided; the generator protective devices may trip the unit in this speed range, regardless of load. This is not applicable to emergency generators.

7-11.7.2 Motor Speed.

Motor-driven auxiliaries will slow down, reducing generator output. Safety margins in generator-cooling and bearing lubricating systems will be reduced. The lowest safe

plant operating speed will depend on the safety margins included in the plant design. However, operation below the 56.6 to 57.5 Hz range is generally not advisable.

7-11.7.3 Other Implications.

In some cases, the selection of critical loads must be made on a purely subjective basis, considering the effect on the community of providing power or of not providing power to a specific load during a widespread power failure.

7-12 OPERATIONAL CONSIDERATIONS.

7-12.1 Isolated Operation.

Under isolated operation, the generator operates independently of the electric utility and provides all electricity and steam needed and used by the facilities that it serves.

7-12.2 Base Loads.

Under base load electric operation, the cogeneration equipment is sized and installed to generate electricity at a constant (base) load equal to the minimum annual (or some other period) electrical demand.

7-12.3 Alternate Energy Sources.

Variable renewable energy sources do not operate in parallel with mission-critical generation.

7-13 POWER PLANT OPERATIONS.

7-13.1 Power Plant Supervisors.

Power plant supervisor’s and operator’s responsibilities are set by each Service.

7-13.2 Work Schedule

Work in three shifts, 24 hours per day, all year. Schedule maintenance shifts, one shift or two, based upon size of the facility and have an on-call program to call maintenance personnel in case of an emergency.

7-13.3 Dead Plant Start-Up.

To start up power plants that are in the dead state, the operator must:

1) Ensure all loads to external switchgear are disconnected.
2) Ensure there is air for starting air-operated generators or battery power for generator starting.
3) If air or battery power is not available, start the black start generator manually if it has not started automatically. Energize lighting, fuel pumps, lube oil, and controls from the black start bus.

4) If there is no black start generator, use utility power to provide power to the plant controls, fuel pumps, lube oil, and lighting.

5) Once the black start bus has been energized, and all controls are activated, the prime power generator may be started. Start by making sure the fuel pumps, lube oil, and controls are operational. When this generator is started and running, energize the main bus and then synchronize to either the utility or another generator.

6) After one or more generators have been energized, pick up loads one-by-one and add onto the generator.

7) When all loads have been picked up and the power plant is operating in normal mode, shut down the black start generator and prepare it for the next occurrence.

7-13.4 Power Outage.

Ensure scheduled outages are communicated to all affected parties. Communicate unscheduled outage information to all applicable parties as soon as possible. Include the reason for the outage and, if the plant has not been re-started, an estimated plant restart time.

7-13.5 Emergency Plant Shutdown.

Emergency plant shutdown procedures are required for potential abnormal operating conditions, fire, or other natural event that may occur and damage or disrupt facility power generation. Ensure approved emergency plant shutdown procedures are readily available in the main plant control room and the procedures have clear roles and responsibilities for plant personnel duties. The procedures must ensure the following:

- Plant shutdown without injury to personnel, damage to equipment, and damage to the environment
- Minimum environmental emissions
- Protect equipment from over-pressure or over-temperature damage

7-13.6 Micro-Grid Operation.

The Department of Energy defines a micro-grid as, “A group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that act as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid connected or island mode.” Only use micro-grid operations when feasible and when they do not interfere with mission-critical standby/emergency generators according to Service guidance and policy.

7-13.6.1 Island Mode.

There are three events to cause a transition to island mode:

- Emergency situation when a utility outage occurs and sufficient generation is available
- Black start when an outage occurs and sufficient generation is **not** online
- Planned island mode required due to combat situations, forecasts in unfavorable weather, and economic situations

7-13.6.2 Typical Island Mode Operational Sequence.

The typical operator actions for the island mode operations sequence include:

1) Operator finds out about an emergency.
2) The plant is islanded from the utility using breaker controls.
3) Additional generators are started to have rolling reserve capacity.
4) Enable load restoration of shed loads if any have been shed when emergency disconnect occurred.
5) If the emergency has passed, make sure that frequency and voltage in island operations are within tolerance ranges.
6) Re-synchronize, when possible.

7-14 OPERATIONAL PERMITTING.

See NERC Standard PRC-005-2, *Protection System Maintenance Program*, as appropriate for large systems over 75 MVA in total or 20 MVA individually.

7-14.1 Wastewater Discharge Permit.

As appropriate, obtain a National Pollutant Discharge Elimination System (NPDES) permit in accordance with the Clean Water Act (CWA). Renew the permit every five years or per the requirements of the issuing authority.

7-14.2 FAA Permit.

For prime power facilities located in the flight path of airports and heliports, obtain FAA permitting for exterior maintenance activities that exceed the height of existing facilities, could affect flight operations, or the stack height changes. Consult the FAA Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) (https://oeaaa.faa.gov/oeaaa/external/portal.jsp). This process should start with the nearest FAA Airports Regional Office. This is covered under 14 CFR 77, *Safe, Efficient Use, and Preservation of the Navigable Airspace*.

7-14.3 Incidental Take.

Obtain permits and retain compliance records required under the Endangered Species Act of 1973 for activities that may “take” (kill) native threatened or endangered species. Contact the nearest U.S. Fish and Wildlife Service (USFWS) Ecological Services Office to determine if the proposed facility is likely to result in a take, whether a permit is

required, or if other options require consideration. Obtain an Incidental Take Permit in accordance with 50 CFR Part 13 and 50 CFR Part 17.

7-15 PREVENTIVE MAINTENANCE.

Table 7-1 provides a typical prime generator maintenance schedule. Review EPA regulations to ensure EPA-required O&M frequencies/practices for key systems have been incorporated into inspection and maintenance. Ensure requirements in 40 CFR Part 63 Subpart ZZZZ, 40 CFR Part 60 Subpart JJJJ, 40 CFR Part 60 Subpart IIII, and 40 CFR Part 89 are not violated (when applicable, based on generator age and location).

7-15.1 Corrosion Control.

Prime power plants have elements that can fail due to corrosion and cause equipment failure or create a life safety risk. Preventive maintenance must include corrosion control for the following elements: boilers, steam drums, feed water heaters, super heater, turbine, pipes, cooling tower, and structural supports.

Table 7-1 Typical Prime Generator Maintenance Schedule

Item/Component	Action					Frequency					
	Visual Inspection	Check	Change / Replace	Clean	Test	Daily	Weekly	Monthly	Quarterly	6 Months	Yearly
Prime Mover											
General Inspection	X						X				
Service air cleaner			X	X						X	
Governor oil level and linkage	X	X						X			
Governor oil			X								X
Ignition system	X	X	X	X	X						X
Choke setting and carburetor adjustment		X								X	
Injector pump and injectors					X						X
Generator											
Brushes	X	X		X						X	
Commutators and slip rings	X			X							X
Rotor and stator	X			X							X
Bearings	X		X								X
Bearing grease		X	X								X
Exciter	X	X		X							X
Voltage regulator	X	X		X							X
Resistance and insulation					X						X
Fuel System											
Main supply tank level		X					X				
Day tank level	X	X					X				
Tank float switch	X				X		X				
Transfer pump operation	X				X		X				
Solenoid valve operation	X				X		X				
Strainer and filter				X					X		
Water in system		X		X			X				
Flexible hose and connectors	X		X				X				
Tank vents		X			X						X
Piping	X										X
Lubrication System											
Oil level	X	X					X				
Oil change			X								X
Oil filter			X								X
Lube oil heater		X									X
Crankcase breather	X		X	X					X		

Item/Component	Action					Frequency					
	Visual Inspection	Check	Change / Replace	Clean	Test	Daily	Weekly	Monthly	Quarterly	6 Months	Yearly
Cooling System											
Level	X	X					X				
Antifreeze protection level					X					X	
Antifreeze			X				X				
Cooling water to heat exchanger		X					X				
Rod out heat exchanger				X							X
Fresh air through radiator		X					X				
Exterior of radiator				X							X
Fan and alternator belt	X	X						X			
Water pumps	X						X				
Flexible hose and connectors	X	X					X				
Jacket water heater		X					X				
Duct work and louvers	X	X		X							X
Louver motors and controls	X			X	X						X
Exhaust Systems											
Leakage	X	X					X				
Drain condensate trap		X					X				
Insulation	X								X		
Excessive backpressure					X						X
Exhaust system hangers and supports	X										X
Flexible exhaust sections	X									X	
Battery Systems											
Electrolyte level		X					X				
Cleanliness and tightness of terminals	X	X							X		
Corrosion	X			X				X			
State of charge					X			X			
Charger and charge rate	X							X			
Equalize charge		X						X			
Electrical System											
Transfer Switches											
Insulation resistance (p-p and p-grnd)					X						X
Contact resistance					X						X
Manual transfer switch operation					X						X
Transfer switch alarms	X				X						X
Transfer switch indicating lights	X				X						X

Item/Component	Action					Frequency					
	Visual Inspection	Check	Change / Replace	Clean	Test	Daily	Weekly	Monthly	Quarterly	6 Months	Yearly
Transformers											
Cleanliness	X									X	
Electrical insulation discoloration	X										X
Oil acidity					X						X
Discoloration	X				X						X
Dielectric strength					X						X
Transformer cooling system		X									X
Transformer alarms	X										X
Switchgear											
Carbon tracks on switchgear	X										X
Barriers and shutters	X										X
Insulation resistance (p-p and p-grnd)					X						X
Dielectric absorption					X						X
Power factor					X						X

7-16 BAGHOUSE LEAK DETECTION AND PERFORMANCE MEASUREMENTS.

7-16.1 Inspection.

Each sensor should be inspected at regular intervals to remove any buildup of material that may collect on the probe or insulator. A buildup of material on the probe may dampen or decrease the signal strength and material on the insulator can form a conductive electrical bridge across the insulator, increasing the signal strength and resulting in a high alarm.

7-16.2 Trial Period.

An initial 30-day trial period is recommended to verify the setup of the instrument is appropriate in order to prevent frequent false alarms and ensure the instrument has sufficient detection capability. Another reason such a trial period is recommended is to verify the system selected will perform reliably in the application and the environment to which it is exposed. Some monitors may have higher sensitivity upon initial installation but over a period of several days will stabilize and remain repeatable. The monitor lacks the ability to compensate for a buildup of particulate on the probe, so conditioning the system to the process environment is critical to reliable and repeatable operation.

After the sensitivity, response time, alarm levels, and alarm delay (if applicable) have been set and undergone the 30-day trial period, they should not be readjusted unless

normal process conditions change in a manner that affects the characteristics of the particles or exhaust gas stream, such as:

- Change out of filter bags, repair of leaks, or other process improvement that would reduce particulate emissions.
- Slow drift of signal due to environmental factors such as humidity. If the sensitivity drifts more than -50 to 100 percent from the initial setup, the monitoring system and control device should be inspected and any necessary repairs performed.
- Equipment is taken out of service for repair, replacement, or upgrading.

7-17 SPECIALIZED INSPECTIONS (GAS TURBINE ONLY).

7-17.1 Borescope Inspection.

Conduct a borescope inspection of all compressor stages, buckets, and nozzles annually for natural gas and distillate fuels or semi-annually for heavy fuel oils. Inspect for signs of excessive gas path fouling, symptoms of surface degradation (such as erosion, corrosion, or spalling), displaced components, deformation or object damage, material loss, nicks, dents, cracking, indications of contact or rubbing, or other anomalous conditions.

7-17.2 Hot Gas Path Inspection.

Conduct an inspection of the turbine hot gas path at intervals recommended by the manufacturer (typically 24,000 hours) in accordance with the manufacturer's O&M manual requirements.

- Inspect condition of nozzles, nozzle seals and hook fits, diaphragms, and diaphragm packings.
- Inspect bucket seals and cutter teeth on tip shroud buckets.
- Inspect turbine rotor and compressor.
- Inspect turbine shell.

7-17.3 Major Inspection.

Conduct a major inspection of the gas turbine at intervals recommended by the manufacturer (typically 48,000 hours) in accordance with the manufacturer's O&M manual requirements. Inspection includes hot gas path inspection items and the following:

- Inspect casings, frames, and diffusers.
- Inspect compressor inlet and compressor flow paths.
- Inspect rotor and stator compressor blades and check tip clearance.

- Conduct a non-destructive inspection (NDI) of turbine buckets and wheel dovetails.
- Inspect bearings, liners, and seals.
- Inspect compressor and compressor discharge case and inner barrel.
- Check gas turbine to generator alignment.

7-17.3.1 Step-Up Transformers Associated with Power Plant.

- Check transformers for electrical insulation discoloration.
- Perform dielectric strength tests to insulating oil for liquid-filled transformers in accordance with ASTM D877, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*.
- Perform acidity tests to insulating oil for liquid-filled transformers in accordance with ASTM D1534, *Standard Test Method for Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration*.
- Perform color test to insulating oil for liquid-filled transformers in accordance with ASTM D1524, *Standard Test Method for Visual Examination of Used Electrical Insulating Liquids in the Field*.
- Check damage on cooling system equipment for transformers equipped with forced-cooling systems.
- Test for transformer alarm condition activation (temperature, level, pressure), if equipped.
- Check that cooling passages for transformers are not being fouled by dust.
- Remove and test transformer oil to record its temperature and observe if it is in optimum working condition.
- Perform the following tests:
    - Power factor/dissipation factor test
    - Dissolved gas/chromatograph test
    - Karl Fischer moisture test
    - Furanic compound test
    - Total dissolved combustible gases ppm
    - Dissolved metals test
    - Appearance
    - Dielectric breakdown test
    - Test on transformer oil every three years

7-17.3.2 Cable Testing of Medium Voltage Cables.

Periodic maintenance tests are needed during the life of the cable to determine whether or not there has been significant insulation deterioration due to operational or environmental conditions. The maintenance schedule for power cables only pertains to cables associated with critical equipment. High potential tests (hipot) effectively reduce in service failures from faults of the cable or its accessories. When done properly, maintenance tests can detect problems in cables that are approaching failure without accelerating the deterioration process. Except for infrared scanning, de-energize the cable circuit before maintenance. An insulation test using a DC ramp test is recommended at a five-year interval.

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CHAPTER 8 AIR FORCE REQUIREMENTS

8-1 SUMMARY OF REQUIREMENTS.

This chapter supplements AFI 32-1062 and applies to Air Force real property installed equipment (RPIE) and equipment authorized inventory data (EAID) electrical generator systems, inspection, maintenance, testing, and refueling criteria. The BCE or equivalent will operate, and maintain all RPIE electrical generator systems and equipment, including EAID electrical generators and equipment assigned to the BCE. Electrical generator systems not assigned to the BCE should have a signed memorandum of agreement (MOA) on file. Perform preventive maintenance in accordance with approved Air Force preventive maintenance procedures prescribed by AFI 32-1001, *Operations Management*, and testing requirement frequency outlined in this chapter. Documentation of preventive maintenance actions, electrical generator system testing (e.g., test records, run-times, electrical testing parameters), oil analysis results, and system repairs must be documented by the BCE. The Air Force Air Program Information Management System (APIMS), in accordance with recordkeeping requirements of AFI 32-7040, *Air Quality Compliance and Resource Management*, is recognized as an official record. The BCE is encouraged to use APIMS as their official record; however, if a shop uses APIMS as the official shop record then the shop must upload and manage the information in APIMS.

8-2 DEFINITIONS.

8-2.1 Standby power is an alternate power source that is available through either automatic or manual operation. Standby power may be RPIE or EAID based on AFCEC/COSM authorization.

8-2.2 Prime power is standby power capable of operating continuously. The generator may be considered prime when the utility source is not available or unreliable. Generators designed to operate in parallel with the utility are also considered to be prime power.

8-2.3 Backup generators may be RPIE or EAID portable units. RPIE generators support mission-critical functions where delayed power restoration is unacceptable. RPIE generators may be approved for missions that require immediate power restoration, uninterrupted power, or support to **\1** standby **/1/** systems defined in NFPA 70, *National Electrical Code* (NEC), Article 700. EAID generators support mission-critical or infrastructure-critical functions where delayed power restoration is acceptable. During a commercial power outage, a lack of infrastructure-critical function could result in an environmental or other non-mission-related condition.

8-2.4 Classifications of generator authorizations: RPIE – Emergency **\1** (same facility life-safety systems, i.e., not mission systems), **/1/** RPIE – COPS, RPIE – POLS/Fuels, RPIE – Other Permanently Installed; EAID – Portable, and EAID – POLS/Fuels. Refer to AFI 32-1062 for definitions or classifications and approval process.

8-2.5 Deployable generators are defined as those assigned to a Civil Engineering (CE) Squadron unit type code (UTC).

8-3 GENERATOR PREVENTIVE MAINTENANCE FREQUENCIES, MAINTENANCE REQUIREMENTS, AND TESTING.

- The minimum inspection and testing frequencies required for RPIE and EAID generator systems are prescribed in Table 8-1.
- Use the approved Air Force Preventive Maintenance Task List (AF-PMTL) for the required maintenance procedures per AFI 32-1001 on RPIE and EAID generator systems.
- AF-PMTLs are built to address reoccurring Air Force preventive maintenance requirements, common manufacturer's preventive maintenance requirements, and preventive maintenance requirements outlined in NEC Articles 700, 701, 702, 705, and 708, and in NFPA 110 (Level 1 and 2).
- AF-PMTLs do not address unique local laws, regulations, and uncommon manufacturer's unique reoccurring preventive maintenance. Coordinate local supplements to AF-PMTLs through the AFCEC/COO Preventive Maintenance Program Manager.

8-3.1 Requirements for Select Mission-Essential Facilities Compliance with Published Guidance.

- Exercise other **\1** standby ***/1/*** systems supporting navigational aids for air traffic control facilities according to AFI 13-204V3, *Airfield Operations Procedures and Programs,* in addition to requirements in this chapter.
- **\1** Exercise other standby systems supporting Defense Communications Systems (DCS) or related communications activities according to Defense Information Systems Agency Circular (DISAC) 350-195-2*, *Tests and Evaluations - Electric Power Systems for Department of Defense Information Network (DODIN) Facilities.* ***/1/***
- Exercise emergency power systems that support medical facilities according to NFPA 99, *Health Care Facilities Code*, in addition to requirements in this chapter.
- Generator systems required to comply with NEC Article 708 must also comply with NFPA 110 Level 2 criteria. **\1** Application of NEC Article 708 is more costly than the other generator requirements of the NEC. ***/1/***

Table 8-1 Generator System Inspection and Testing Frequency Requirements

Classification (ref: AFI 32-1062)	Preventive Maintenance / Inspection Frequency				
	Semi-Monthly[3](J)	Monthly (M)	Quarterly (Q)	Semi-Annual (SA)	Annual (A)
RPIE - Emergency	X	X		X	
RPIE - COPS	X	X		X	
RPIE - POL/FUELS		X	X		X
RPIE - Other Permanently Installed	X	X		X	
EAID - Portable		X	X		X
EAID - POL/Fuels		X	X		X
Supporting Equipment					
Transfer switch (ATS / MTS / paralleling switchgear)[1]	X	X	X	X	X
Fuel system[2]	X	X	X	X	X

Terms:

Semi-monthly: Twice a month; activities are generally separated by enough time so the occurrences are equally distributed across the month

Monthly: Once a month

Quarterly: Once every three months

Semi-Annual: Once six months

Annual: Once a year

Notes:

1: Inspect ATS / MTS / paralleling switchgear during each required PM frequency for the generator it is supporting.

2: Inspect fuel system during each required PM frequency for the generator it is supporting.

3: Geographically separated equipment located more than 20 miles (32 km) from the servicing installation may be inspected monthly if the batteries and generator operation are monitored by a remote monitoring system complying with UFC 4-010-06.

8-3.2 RPIE Generator and Transfer Switch Inspections and Operational Testing Requirements.

This section addresses generator system operational testing requirements for RPIE generator systems classified by AFCEC/COSM as RPIE - Emergency, RPIE – COPS, and RPIE - Other Permanently Installed.

Document all inspection actions on AF Form 487, *Generator Operating Log (Inspection Checklist)*, and file the form with the generator record.

8-3.2.1 Semi-monthly RPIE Generator and Transfer Switch Inspections.

Conduct and document visual inspection of the generator, ATS/MTS/switchgear, and system batteries. Engine start is optional.

8-3.2.2 Monthly RPIE Generator and Transfer Switch Testing.

Test the RPIE generator system monthly by exercising the generator for a minimum of one hour using either Exercising Method 1 or 2. Load generator with facility load first, annotate load on AF Form 487 and, if facility load is not adequate to meet minimum operating conditions for the selected Exercising Method, use a load bank in combination with facility load to increase the total load on the generator to meet the Exercising Method. Test generator systems monthly under facility load with the electrical service entrance to the transfer switch/switchgear switched off.

8-3.2.2.1 Monthly Generator Exercising Method 1.

Conduct this test under loading that maintains the minimum exhaust gas temperature (EGT) recommended by the manufacturer. The one-hour generator exercise time for Method 1 operational inspections includes warmup, load test, and cool-down.

8-3.2.2.2 Monthly Generator Exercising Method 2.

Conduct this test under operating temperature conditions and at no less than 50 percent of the generator nameplate kW rating. The one-hour generator exercise time for Method 2 operational inspections includes warmup, load test, and cool down.

Note: RPIE generators rated 25 kW and lower are not required to meet monthly generator Exercising Method 1 or 2 and shall be tested with actual facility loads for a minimum of one hour.

Note: Additional semiannual testing is required if a monthly test accomplished between semiannual tests does not meet the requirements of either monthly generator Exercising Method 1 or 2.

8-3.2.2.3 Monthly Exercising of \1\ MTS/Switchgear. /1/

Test the **\1** MTS/switchgear **/1/** monthly by exercising the operation of the switch with facility loads. The monthly test of the switch must consist of operating the switch from its primary position to the electrical generator power source position and then return to the primary position upon completion of the generator test.

The criteria set forth in NFPA 110 Section 4.3 and Table 4.1(b) is not required during the monthly testing of the EPSS.

8-3.2.2.4 Monthly Exercising of Paralleling Switchgear.

Test the paralleling switchgear monthly by exercising the operation of the paralleling switchgear with facility loads. The monthly test of the paralleling switchgear must consist of operating the paralleling switchgear, paralleling of the connected generators, and operating the switchgear from its primary position to the electrical generator power source position and then return to the primary position upon completion of the generator test.

8-3.2.3 Semiannual RPIE Generator Full-System Testing.

Test the full generator system semiannually with the facility electrical service entrance power switched off upstream of the facility for a minimum of one hour. **\1** A longer generator test of greater than one hour is strongly encouraged on an annual basis to verify the proper configuration and operation of all downstream loads. **/1/** Testing conducted with only the power source disconnected to the transfer switch/switchgear will only test the generator system and does not assure that mission equipment and facility support equipment are connected to the correct electrical distribution panels. Testing the generator system with the facility electrical service entrance power switched off upstream of the facility verifies which mission equipment and facility support equipment is sustained by the generator system and which portions of the facility are not sustained by the generator system. **\1** Where multiple generators provide standby power to the same facility, a custom test plan must be developed to verify proper configuration and operation. **/1/**

Note: Additional semiannual testing is required if a monthly test accomplished between semiannual tests does not meet the requirements of either monthly generator Exercising Method 1 or 2. For generator systems not meeting the monthly testing methods, load the generator system with available facility load (augmented with load banks, as necessary) to achieve not less than 50 percent of the generator nameplate kW rating for one continuous hour and then not less than 75 percent of the generator nameplate kW rating for one additional continuous hour, for a total test duration of not less than two continuous hours.

8-3.2.3.1 Exemptions to Semiannual Inspection and Testing.

Generators supporting an actual power outage during a six-month period do not require an additional semiannual full-system test, provided the following conditions are met:

- The outage duration was at least one hour. Separate outages cannot be added together to meet this requirement.
- The transfer switch operated properly during the outage.
- All items were checked/annotated on AF Form 487, including the facility representative section.
- A post-operational inspection was accomplished.
- **\1** Generator load was greater than 50 percent. **/1/**

8-3.2.3.2 Denial Authority for Semiannual Testing.

Refer to AFI 32-1062 regarding denial of semiannual RPIE generator full-system testing.

8-3.3 RPIE POL/Fuels Generator and Transfer Switch Testing.

This section addresses generator system operational testing requirements for RPIE generator systems classified by AFCEC/COSM as RPIE POL/Fuels.

Document all inspection actions on AF Form 487, Generator Operating Log (Inspection Check List) and file the form with the generator record.

8-3.3.1 Monthly RPIE POL/Fuels Inspections and Testing.

Conduct and document visual inspection of the generator, ATS/MTS/switchgear, and system batteries. Engine start is required.

8-3.3.2 Quarterly RPIE POL/Fuels Testing.

Test the RPIE POL/Fuels generator system quarterly by exercising the generator system for a minimum of one hour using the designed pumping capability. Verify operation of transfer switch or interlocked switching devices.

8-3.3.3 Annual RPIE POL/Fuel Testing.

Test the RPIE POL/Fuels generator system annually by exercising the generator with a load bank, as necessary to achieve not less than 50 percent of the generator nameplate kW rating for one continuous hour and not less than 75 percent of the generator nameplate kW rating for one continuous hour, for a total test duration of not less than two continuous hours. Facility load is not required during annual test.

8-3.4 EAID Generator and Transfer Switch Inspections and Operational Testing Requirements.

This section addresses generator system operational testing requirements for EAID generator systems classified by AFCEC/COSM as EAID Portable and EAID POL/Fuels.

Document all inspection actions on AF Form 487 and file the form with the generator record.

8-3.4.1 Monthly EAID Inspections and Testing.

Conduct and document visual inspection of the generator, ATS / MTS / Switchgear, and system batteries. Engine start is required.

8-3.4.2 Quarterly EAID Testing.

Test the EAID generator system quarterly by exercising the generator system with a load bank to achieve not less than 50 percent of the generator nameplate kW rating for 30 continuous minutes and not less than 75 percent of the generator nameplate kW rating for one continuous hour, for a total test duration of not less than 90 continuous minutes.

8-3.4.3 Annual EAID Testing.

Test the EAID generator system annually by exercising the EAID generator system connected to the facility or system they primarily support, transfer facility, or system electrical load to the EAID generator. Exercise the generator for one continuous hour.

Test the ATS/MTS/switchgear connected to the EAID generator by exercising the operation of the switch with facility loads. The test of the switch must consist of operating the switch from its primary position to the electrical generator power source position and then return to the primary position upon completion of the generator test.

The criteria set forth in NFPA 110 Section 4.3 and Table 4.1(b) is not required during EAID generator system testing.

8-3.4.4 Portable Generator Facility Connections.

Portable generator facility connections must comply with UFC 3-540-01. Generator connections described in UFC 3-540-01 cannot also be used as an emergency means of isolation required by the NEC.

Inspect portable generator electrical connection plugs and receptacles for corrosion before each use. Repair as necessary and coat contacts with proper electrical connection corrosion-preventive compound.

8-3.5 Deployable Generator Inspections and Testing.

This section addresses generator system inspection and testing for generators defined as deployable generators.

Deployable generators are defined as those assigned to a CE Squadron UTC.

Document all inspection actions on AF Form 487 and AF Form 719, *Historical Record – Diesel-Electric Generator and System*, and file the forms with the deployable generator record.

8-3.5.1 Deployable Generators Testing Upon Receipt.

Power production personnel must test CE deployable generators upon initial receipt. After testing and documenting operating parameters, purge, shelve, and prepare the generators for immediate deployment.

8-3.5.2 Annual Inspection and Operational Testing.

Inspect and operationally test CE deployable generators annually for a minimum of one continuous hour while loaded to at least 75 percent of rated capacity.

8-3.5.3 CE Deployable Generator Maintenance.

Maintain CE deployable generators in accordance with T.O. data or manufacturer’s manuals.

8-3.5.4 Non-CE Deployable Generators.

Maintenance, testing, and operation of non-CE deployable generators (e.g., Combat Communication, Air Control Squadron, and Maintenance Squadron) are governed by their own T.O.s or the manufacturer's guidance instead of this chapter.

8-4 MISSION UNINTERRUPTIBLE POWER SUPPLIES (UPS).

\1 [Deleted paragraph] **/1/**

Mission operators, e.g. UPS owner, should not plan for UPS support longer than 15 minutes. If generators do not operate correctly during commercial power outages, mission operators should take immediate actions following their established mission shut-down and transfer processes to avoid mission disruption and equipment damage. During generator inspection and testing events, the mission operator should monitor their UPS status to ensure they do not falsely conclude the mission load was carried by the generator.

\1\ Note: Power condition and continuation interfacing equipment (PCCIE), which typically includes UPSs, is classified as equipment and must be owned by the mission and not the BCE. For guidance on acquisition and maintenance of UPS equipment, contact the PCCIE Product Group Manager, 500 CBSS/GBLD, Building 1207-N, 6029 Wardleigh Road, Hill AFB, UT 84056-5838. **/1/**

8-5 LUBRICATING OILS.

Follow the engine manufacturer's recommendations for the type and grade of oil as closely as possible. Lubricating oils satisfying minimum requirements of military specifications MIL-PRF-2104, *Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service*, and MIL-PRF-46167, *Lubricating Oil, Internal Combustion Engine, Arctic*, are acceptable for many diesel engines but may not be adequate for some high-speed engines.

Confirm the suitability of military specification lubricating oils with the engine manufacturer before use.

This section addresses deviations from manufacturer's service intervals for RPIE and EAID generator engine lubrication systems.

8-5.1 Deviation from Manufacturer's Service Intervals.

Refer to AFI 32-1062 regarding deviation authority from manufacturer's service intervals.

8-5.1.1 RPIE Oil Change Interval Deviations.

RPIE generator engine oil change intervals may be extended from the manufacturer's specified service interval to 24 months or 1,000 engine hours between engine oil and oil filter change if all of the following apply:

- Ensure requirements in 40 CFR Part 63 Subpart ZZZZ (all stationary prime power generators), 40 CFR Part 60 Subpart JJJJ (all stationary spark ignition [SI] generators), 40 CFR Part 60 Subpart IIII (all stationary compression ignition [CI] generators), and 40 CFR Part 89 (portable diesel generators), are not violated (when applicable, based on generator age and location).
- Verify the RPIE generator is not under warranty and is at least three years old.
- Ensure oil change interval never exceeds 24 months or 1,000 engine hours of operation.
- Verify oil analysis results conducted at the same frequency specified for changing the oil are within the required limits specified by the manufacturer and 40 CFR Part 60 Subpart IIII and 40 CFR Part 63 Subpart ZZZZ paragraph 63.6625(i). The analysis must include viscosity, acid content, particulates, water, or other contaminants, and recommended actions after results are provided. Total engine hours and time since last oil change must be printed on the oil analysis results.
- **\1** [Deleted text] **/1/**
- Ensure the servicing environmental office is engaged to determine if deviation affects permitting requirements.
- Maintain a copy of the approved deviation memo with the RPIE generator maintenance record.

8-5.1.2 EAID Oil Change Interval Deviations.

EAID generator engine oil change intervals may be deferred up to 12 months from the manufacturer's specified service interval if all of the following apply:

- Verify the EAID generator is not under warranty.
- Ensure oil change interval never exceeds 24 months or 1,000 engine hours of operation.
- Total operating hours are less than 150 within the last 12 months.
- Verify oil analysis results conducted at the same frequency specified for changing the oil are within the required limits specified by the manufacturer and 40 CFR Part 60 Subpart IIII and 40 CFR Part 63 Subpart ZZZZ paragraph 63.6625(i). The analysis must include viscosity, acid content, particulates, water, or other contaminants, and recommended actions after results are provided. Total engine hours and time since last oil change must be printed on the oil analysis results.
- **\1** [Deleted text] **/1/**

- Ensure the servicing environmental office is engaged to determine if deviation affects permitting requirements.

- Maintain a copy of the approved deviation memo with the RPIE generator maintenance record.

8-5.1.3 Oil Analysis.

Oil analysis requirements (40 CFR 63.6625 condemning factors: total base number is less than 30 percent of the total base number of the oil when new; viscosity of the oil has changed by more than 20 percent from the viscosity of the oil when new; or percent water content [by volume] is greater than 0.5) are in 40 CFR Part 63 Subpart ZZZZ. The oil analysis must be part of an oil analysis program and included in the engine's maintenance plan. If any of the condemning limits are exceeded, the oil must be changed within two business days of receiving the results.

Sample in accordance with manufacturer's recommendations and field test using oil analysis kit NSN 6630-01-096-4792, *Test Kit, Oil Condition*, or an independent oil analysis company test kit (e.g., Cummins Filtration #CC2543, Caterpillar S•O•SSM, Wix filters; verify the kit meets EPA requirements). Record results on AF Form 487 and AF Form 719. If an approved field test kit is not available or the above tests are not performed, the oil must be changed.

8-6 FUELS.

This section addresses fuel types approved for use with RPIE and EAID generator systems, fuel-related training, fuel tanks, and fuel supply.

8-6.1 Fuel Oils.

\1 Fuel oils used for RPIE and EAID generators must meet ASTM D975, *Standard Specification for Diesel Fuel Oils*, or European Committee for Standardization EN 590, *Automotive Fuels - Diesel - Requirements and Test Methods*, or host nation equivalent. Consult T.O. 42B-1-1, *Quality Control of Fuels*, for additional information. Follow the specific temperature and applicable service conditions and ensure sulfur content does not exceed environmental restrictions or original equipment manufacturer's fuel requirements. Do not mix different grades of fuel. Consult T.O. 42B-1-1 and MIL-STD-3004-1, *Quality Assurance for Bulk Fuels, Lubricants and Related Products*, for additional information. Comply with 40 CFR 60.4207 (stationary CI internal combustion engines) and 60.4216 (engines located in Alaska). ***/1/***

8-6.2 Jet Fuels.

\1 Jet fuel potentially may be used with required additives when diesel is not available. Consult AFCEC/CO or the installation environmental office and the EPA for emission restrictions. Deviation from requirements to use diesel fuel in 40 CFR 60.4207 can be authorized through the provisions of 40 CFR 60.4216, 60.4217, or 40 CFR 1068.225 (National Security Exemption) where applicable. Use of non-standard fuels in diesel equipment may incur significant costs for testing and permitting efforts. Consult T.O.

42B-1-1 for more information. Consult the manufacturer for kW de-rating when using JP-8, JP-5, TS-1, F-24 (Jet A with additives), Jet A-1, or Jet A. **/1/**

8-6.3 Natural Gas, Liquid Petroleum Gas, and Bio-Diesel.

\1 Use of natural gas (NG), liquid petroleum gas (LPG), or bio-diesel/bio-diesel blend fuels is not permitted for RPIE or EAID generator authorizations. NG, LPG, or alternative fuels (renewable diesel fuel blend where the alternative fuel is produced using a hydro-treating process) may be authorized for prime power generation or co-generation. BCEs must either program existing generators that use NG, LPG, or bio-diesel/bio-diesel blend for replacement within five years or request a waiver from AFCEC/CO for continued operation. Consult T.O. 42B-1-1. BCEs will ensure refueling plans address backup fuel support for existing generators using NG or LPG in the event of fuel supply disruption.

Rewrite paragraph A-7.1 of this UFC to read: "Diesel fuel should comply with ASTM D975, EN 590, or host nation equivalent. These specifications include winter (No. 1) and summer (No. 2) grades available as both low sulfur and ultra-low sulfur. All are suitable for use under applicable temperature and service conditions. Alternately, MIL-DTL 83133 (JP-8), MIL-DTL-5624 (JP-5), or MIL-DTL-16884 (F-76) can be used as a diesel fuel substitute, noting that all have a high sulfur content and are not suitable for equipment requiring low sulfur or ultra-low sulfur diesel fuels. Different grades of fuel should not be mixed. It should be noted that all diesel specifications allow for a limited content of bio-diesel. Consult T.O. 42B-1-1 for additional information." **/1/**

8-6.4 Fuel Storage Tank Training.

Personnel must be trained to manage fuel storage tanks in accordance with AFI 23-204, *Organizational Fuel Tanks*.

8-6.5 Fuel Tanks of Emergency Generators.

Emergency generator fuel tanks must comply with requirements of NFPA 30, *Flammable and Combustible Liquids Code*, NFPA 37, *Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines*, NFPA 54, *National Fuel Gas Code*, NFPA 58, *Liquefied Petroleum Gas Code*, NFPA 110, and applicable state regulations.

8-6.5.1 Fuel Tanks for New Systems.

For new systems, coordinate with BCE's Installation Management Flight to ensure the emergency generator fuel tank is included on the installation Spill Prevention Control and Countermeasures (SPCC) plan per 40 CFR 112 and included in the installation fuel tank inventory per AFI 32-7044, *Storage Tank Environmental Compliance*.

8-6.5.2 Containment.

Provide secondary containment as required by 40 CFR 112 or equivalent where required and at overseas locations.

8-6.5.3 Signage.

Install hazard identification signs as specified in NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, on stationary aboveground tanks or per Final Governing Standards for overseas locations. Ensure storage tanks are marked according to fuel type and warning signs are appropriately located. If an external fuel tank is installed, post a one-line diagram of the fuel system indicating tank size and valve locations.

8-6.5.4 Inspection.

Emergency generator fuel tanks will be inspected monthly and annually as required by AFI 32-7044 with results of inspections posted in the Storage Tank Accounting and Reporting (STAR) system.

8-6.5.5 Fuel Supply.

Plan for and provide a minimum seven-day fuel supply (based on actual generator load), either in a dedicated on-site storage tank or from a confirmed delivery source when a delivery source is used to meet the seven-day requirement. The refueling schedule must take into account the assigned EAID generator tank capacity. RPIE generators will have a minimum 24-hour local capacity based on the actual generator load fuel consumption rate of the engine.

8-7 COOLANT.

The coolant used in diesel engines usually consists of a mixture of ethylene glycol antifreeze, corrosion inhibitor, and fresh water. When the engine is used in an extremely cold area, such as Arctic regions, a special antifreeze mixture is used. Specifications related to the mixtures are as follows:

- **\1** Antifreeze, Ethylene glycol MIL-A-46153
- Specification for cooling system conditioner and inhibitor is MIL-C-10597
- Antifreeze, Ethylene glycol A-A-52624
- Antifreeze, Arctic-type A-A-52624
- 5 Inhibitor, Corrosion MIL-A-53009 or MIL-A-46153 **/1/**

8-7.1 Engine Water Treatment.

8-7.1.1 Acceptable Conditions.

In most modern diesel engines, the following cooling water conditions are acceptable:

- pH 8.5 to 10
- Chloride and sulfate 100 ppm

- Total dissolved solids 500 ppm
- Total hardness 200 ppm

8-7.1.2 Softened Water.

If possible, softened water should be used to reduce the total hardness level of the engine cooling loop. The use of softened water will increase engine performance by reducing the precipitation of calcium and magnesium at elevated temperature conditions, ensuring higher heat transfer rates.

8-7.1.3 Antifreeze.

Typical engine cooling systems incorporate antifreeze solutions that inhibit scale and protect the cooling system when temperatures are encountered below freezing. Ethylene glycol mixed with a corrosion inhibitor such as triazoles form an inhibiting film on metal surfaces that acts as a barrier to the corrosion process. Table A-18 concentrations should be utilized when adding glycol solutions to the engine cooling system.

8-7.1.3.1 Concentration.

The ethylene glycol concentration should exceed 30 percent. If more than 60 percent of solution is added, two effects will be realized: 1) a decrease in heat transfer rates, 2) a lowering of the system freeze protection.

8-7.2 Cooling System Maintenance.

Maintenance consists of periodically testing the antifreeze, inspecting the coolant for cleanliness, and flushing or cleaning the system with compound when necessary.

8-7.2.1 Testing Antifreeze.

Perform tests to verify freeze protection and reserve alkalinity:

- Test for freeze protection using the combination antifreeze and battery tester (stock number 6630-00-105-1418). Instructions for using the tester are included with it.
- Test for reserve alkalinity (corrosion protection) using the reserve alkalinity test kit (stock number 6630-00-169-1506).
- Cooling systems with freeze protection below -7 °F (-22 °C) that fail the reserve alkalinity test may be replenished with corrosion inhibitor (stock number 6850-00-753-4967). Replenishment is a one-time service. If the reserve alkalinity test is failed again, replace the coolant. If the system passes the test, record the date.

8-7.2.2 Inspecting Coolant.

Inspect the coolant visually for cleanliness. Obtain a coolant sample and place it in a clean glass container. After allowing about five minutes for settling, examine the sample for contamination (rust, foreign particles, and/or sediment). The sample may have some color (same color as original antifreeze) and should be clear.

Examine the sample to determine the type and quantity of contamination. Rust, a chemical combination of iron, water, and air, is frequently found. The presence of rubber particles usually indicates deterioration of hoses. Replacement hoses may be indicated. Sediment may be caused by impurities in the water used in the coolant. Contaminants in the coolant can clog a radiator or heat exchanger and cause engine and generating system breakdown.

8-7.2.3 Cleaning the System.

Clean the cooling system whenever the coolant is drained. Usually the system requires nothing more than a thorough flushing with fresh water. Refer to the engine manufacturer's literature for instructions. If any part of the system is rusted or partially clogged, it is necessary to use cooling system cleaning compound and conditioner, stock number 6850-00-598-7328. Do not use the compound as a routine maintenance procedure. Instructions for using the compound are included with it.

8-7.2.4 Filling the System.

Refer to the engine manufacturer's literature for instructions on filling the cooling system. This is applicable to either new systems or those just cleaned and serviced.

8-7.2.4.1 Ethylene Glycol Antifreeze.

Cooling system protection is required for all liquid cooled diesel engines. In areas where temperatures no lower than -55 °F (-48 °C) are expected, prepare a solution according to the information presented in Table A-18. When temperatures below freezing are not expected, use a weak solution such as 1 pint of ethylene glycol antifreeze for each gallon of solution for general protection against rust buildup and scale formation within the engine.

8-7.2.4.2 Arctic-Type Antifreeze.

Use arctic-type antifreeze in areas where temperatures below -55 °F (-48 °C) are expected. Do not dilute arctic-type antifreeze with water or inhibitor; it is ready for use as issued.

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8-8 ACCOUNTING FOR GENERATORS.

8-8.1 RPIE Generators.

Notify the real property office if these generators are temporarily or permanently relocated from one facility to another. Document and account for all RPIE generators awaiting installation in the appropriate work order documents. For excess generators and associated equipment (i.e., ATS), request MAJCOM review and disposition instructions before removing the generator and associated equipment from a RPIE facility. After removing a generator, account for it on DD Form 1149, *Requisition and Invoice/Shipping Document*, if the generator is shipped to another base or to CEMIRT. If the generator is turned in to the Defense Reutilization and Marketing Office, account for it on DD Form 1348-1A, *Issue Release/Receipt Document*.

8-8.2 EAID Generators.

EAID generators are listed in the Allowance Standard (AS), requisitioned from Warner Robins Air Force Life Cycle Management Center (AFLCMC/WNZEC), 235 Byron Street (Building 300-West Wing, Bay D), Robins AFB, GA 31098-1647, DSN 472-1640, commercial (478) 222-1640, and accounted for by Base Supply and AFLCMC/WNZEC. EAID units must be reclassified as RPIE and coordinated with the Item Manager, AFLCMC/WNZEC, when they no longer meet the definition for an EAID or turned in to Base Supply.

8-8.3 AFLCMC/WNZEC.

Report excess EAID generators to AFLCMC/WNZEC. Any RPIE or commercial EAID generators that are no longer required or are inoperable must be identified to the MAJCOM for review and disposition coordination. Disposal of mobile electric power (MEP) EAID generators must first be coordinated with the EAID Item Manager at AFLCMC/WNZEC. If generators are not required or needed by AFLCMC/WNZEC, they must be disposed of in the same manner as RPIE and commercial EAID generators.

8-8.4 Reporting RPIE Generators.

If functional load testing indicates the generator is loaded less than 30 percent of rated capacity over a 12-month period, BCEs will take actions described in paragraphs 8-8.4.1 through 8-8.4.1.2.

8-8.4.1 Compile a list of generators that do not meet the required 30 percent loading for facility loads over a 12-month period. Categorize and certify the generators as “Replacement Eligible,” “Replace by Attrition,” or “Replacement Not Feasible” and document the category in a memo and file it with the generator records.

8-8.4.1.1 RPIE generators used to support large in-rush currents may be sized for starting current. These generators may be excluded from paragraph 8-8.4.1.

8-8.4.1.2 RPIE generators for fire pumps and RPIE generators rated 25 kW and lower are not required to comply with paragraph 8-8.4.1.

8-8.4.2 Any generator installation (new or replacement) and generator removal or relocation requires AFCEC/CZ coordination to ensure EPA clean air compliance regulations are met.

8-8.4.3 Consult with AFCEC/CZ when an EPA-permitted generator is removed from the base; that generator must be removed from the Clean Air Act Title V air permit. Additionally, because the permit requires an accurate list of active permitted generators on base, the BCE must check with AFCEC/CZ to determine if the generator size is small enough to be excluded from the permit.

8-8.4.4 By 1 October each year, MAJCOM senior engineers will review base generator inventory reports and provide AFCEC/COM CEMIRT a list of “Replacement Eligible” generators that cannot be redistributed within their command.

8-8.4.5 By 1 August, BCEs must revalidate the generator authorization memorandum for changes to mission or modifications to the authorized RPIE electrical system and provide a list of “Replacement Eligible” generators to AFCEC/COM.

8-8.4.5.1 AFCEC/COSM must be notified by the BCE when a generator authorization is no longer required.

8-8.4.5.2 The BCE will prepare a plan for all generators that do not have an AFCEC authorization and are available for relocation or disposition. The plan is included as a part of the annual revalidation process. ***/1/***

APPENDIX A SAMPLE O&M PROCEDURES AND FREQUENCY

A-1 STRUCTURE AND ENCLOSURES.

Perform structure and enclosure preventive maintenance per Table A-1.

Table A-1 Structure and Enclosures PM Schedule

Item No.	Maintenance Item	Service Time							
		Daily	Weekly	Bi-Weekly	Monthly	3 Months	6 Months	Yearly	Other
1.0	Structure and Enclosures								
1.1	Exercise damper actuators	X							
1.2	Lubricate door hinges						X		
1.3	Lubricate door locks						X		
1.4	Fastener checks				X				
1.5	Corrosion control checks						X		
1.6	Rodent control checks		X						
2.0	PTO Assemblies/Couplings								
2.1	PTO access door / cover		X						
2.2	Noise checks	X							
2.3	Coupling alignment check							X	
3.0	Bearing Lubrication								
3.1	Rotor bearings								X
3.2	Engine bearings								X
4.0	Belt-Driven Equipment								
4.1	Check Belts for Wear		X						
4.2	Replace drive belts							X	
4.3	Check pulleys/idler wheels			X					

A-1.1 Service Practices.

A-1.1.1 Maintenance Program.

Service practices for diesel engines consist of a complete maintenance program built around records and observations. The maintenance program includes appropriate analysis of these records. DD Form 2744, *Emergency/Auxiliary Generator Operation Log*, should be used to record inspection testing of emergency/auxiliary generators.

A-1.1.1.1 Recordkeeping.

Engine log sheets are an important part of recordkeeping. The sheets must be developed to suit individual applications (i.e., auxiliary use) and related instrumentation. Personnel must use Service-approved forms, such as AFTO Form 781A, *Maintenance Discrepancy and Work Document*, and, for the Air Force, AF Form 487. Accurate records are essential to good operations. Notes should be made of all events that are or appear to be outside of normal range. Detailed reports should be logged. Worn or failed parts should be tagged and protectively stored for possible future reference and failure analysis. This is especially important when specific failures become repetitive over a period of time, which may be years.

A-1.1.1.2 Log Sheet Data.

Log sheets should include engine starts and stops, fuel and lubrication oil consumption, and a cumulative record of the following:

- Hours since last oil change
- Hours since last overhaul
- Total hours on engine
- Selected temperatures and pressures

A-1.1.2 Troubleshooting.

Perform troubleshooting procedures when abnormal operation of the equipment is observed. Maintenance personnel should then refer to log sheets for interpretation and comparison of performance data. Comparisons of operation should be made under similar conditions of load and ambient temperature. The general scheme for troubleshooting is outlined in the following paragraphs.

A-1.1.2.1 Industrial Practices.

Use recognized industrial practices as the general guide for engine servicing. Service information is provided in the manufacturer’s literature and appendixes.

A-1.1.2.2 Reference Literature.

The engine user must refer to manufacturer’s literature for specific information on individual units. For example, refer to Table A-2 for troubleshooting an engine that has developed a problem.

Table A-2 Diesel Engines Troubleshooting

Cause	Remedy
HARD STARTING OR FAILS TO START	
Air intake restricted	Check intake and correct as required.
Fuel shut-off closed	Make sure shut-off is open and supply is at proper level and not low.
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Clogged injector	Clean all injectors.
Injector inlet or drain	Check all connections and correct as required.
Engine due for overhaul	Schedule the overhaul and correct as required.
Incorrect timing	Perform timing procedure.
ENGINE MISSES DURING OPERATION	
Air leaks in fuel suction lines	Check fuel suction lines and correct as required.
Restricted fuel lines	Check fuel lines and correct as required.
Leakage at engine	Refer to manufacturer’s instructions and correct valves as required.
Incorrect timing	Perform timing procedure.
EXCESSIVE SMOKING AT IDLE	
Restricted fuel lines	Check fuel lines and correct as required.
Clogged injector	Clean all injectors. Refer leaking head gasket to manufacturer’s instructions and correct as or blow by.
Engine due for overhaul	Schedule the overhaul and correct.
Incorrect timing	Perform timing procedures.

Cause	Remedy
EXCESSIVE SMOKING UNDER LOAD	
The same causes for “idle” apply	The same remedies for “idle” apply.
Air intake restricted	Check air intake and correct as required.
High exhaust backpressure	Check exhaust system and turbocharger; correct as required.
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Engine overloaded	Reduce load to proper level.
LOW POWER OR LOSS OF POWER	
Air intake restricted	Check air intake and correct as required.
Poor quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Clogged injector	Clean all injectors.
Faulty throttle linkage or governor setting too low	Check linkage and governor; refer to manufacturer’s instructions and correct as required.
Clogged filters and screens	Clean filters and screens.
Engine overloaded	Reduce load to proper level.
Engine due for overhaul	Schedule the overhaul and correct as required.
Incorrect timing	Perform timing procedure.
Engine requires tune-up	Perform tune-up procedure.
DOES NOT REACH GOVERNED SPEED	
The same causes for “low power” apply.	The same remedies for “low power” apply.
EXCESSIVE FUEL CONSUMPTION	
Air intake restricted	Check air intake and correct as required.
High exhaust back-pressure	Check exhaust system and turbocharger; correct as required.

Cause	Remedy
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Faulty injector	Clean all injectors.
Engine overloaded	Reduce load to proper level.
Engine due for overhaul	Schedule the overhaul and correct as required.
Incorrect timing	Perform timing procedure.
ENGINE QUITS	
High exhaust backpressure turbocharger	Check exhaust system and correct as required.
Air intake restricted	Check air intake and correct as required.
Fuel shut-off closed; low supply of fuel	Make sure shut-off is open and supply is at proper level.
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Faulty injector	Clean all injectors.
ENGINE SURGES AT GOVERNED SPEED	
Air leaks in fuel suction lines	Check fuel suction lines and correct as required.
Faulty injector	Clean all injectors.
Leaks in oil system	Check for oil leaks, check oil lines, check crankcase drain plug and gasket; correct as required. Piston rings or cylinder liners may be worn.
Engine due for overhaul	Schedule the overhaul and correct as required.
SLUDGE IN CRANKCASE	
Fouled lubricating oil strainer or filter	Check strainers and filters, remove and service as required, reinstall on engine with new gaskets.

Cause	Remedy
Faulty thermostat	Check coolant thermostats; engine may be too cool.
Dirty lubricating oil	Drain old oil, service strainers and filters, refill with fresh oil.
LUBRICATING OIL DILUTED	
Fuel in lubricating oil	Check for loose injector inlet or drain connection; correct as required. Drain old oil, service strainers and filters, refill with fresh oil.
Coolant in lubricating oil	Check for internal coolant leaks. Correct as required. Drain old oil, service strainers and filters, refill with fresh oil.
LOW LUBRICATING OIL PRESSURE	
Faulty oil line, suction level	**\1** Check oil lines for good condition; fill oil to proper oil level. **/1/** Piston rings, crankshaft bearings, or cylinder liners may be worn.
Engine due for overhaul	Schedule overhaul and correct as required.
ENGINE RUNNING TOO HOT	
High exhaust backpressure	Check exhaust system and turbocharger; correct as required.
Faulty thermostat	Check coolant thermostats; correct as required.
Low lubricating oil level	Fill to proper level with fresh oil.
Engine overload	Reduce load to proper level.
Faulty cooling system component (pump, hose, radiator fan belt)	Check components; correct as required. Fill cooling system to proper level with coolant.
Low coolant level	Air in system. Refer to **\1** TM 5-685, Appendix D. **/1/**

Cause	Remedy
ENGINE KNOCKS	
Poor-quality fuel	Replenish fuel supply with fresh, proper-quality fuel.
Air leaks in fuel suction lines	Check fuel suction lines and correct as required.
Engine overloaded	Reduce load to proper level.
Engine running too hot	Repeat the procedures for “too hot” above.
Faulty vibration damper or flywheel	Correct as required; refer to manufacturer’s instructions.
Engine due for overhaul	Schedule the overhaul and correct as required.

A-1.1.3 Overhaul Procedure.

Engine overhaul requires disassembly of the engine. Verify that all engine parts comply with the manufacturer’s specifications and tolerances.

A-1.1.4 Inspection of Structural Parts.

Inspect structural parts as follows:

- Foundations for deformation and cracks.
- Bedplate for cracks and distortion; bearing supports for good condition.
- Foundation bolts for tightness and general good condition, including straightness.
- Frames for cracks, distortion, and general good condition.
- Cylinders and cylinder blocks for cracks; water jacket areas for corrosion, scale, and rust; machined surfaces for smoothness.
- Cylinder heads for cracks; water jacket areas for corrosion, scale, and rust; valve seats for cracks; machined surfaces for smoothness.
- Covers and gaskets for distortion and cracks; use compliant gaskets only after annealing; use new seals and gaskets other than copper.

A-1.1.5 Moving Parts.

Inspect moving parts as follows:

- Crankshaft for out-of-alignment condition; journal surfaces for highly polished condition and absence of scratches, nicks, etc.; and counterweights, gears, and flywheels for proper condition. Verify that crankshaft complies with manufacturer's requirements. An engine crankshaft is a costly and vulnerable component. Special care in handling is required. Accurate alignment is essential to good engine operation. Removal or installation may require hoisting. Refer to the manufacturer's instructions for details and proper procedures.
- Main bearings for highly polished condition, cracks, deformation and absence of scratches, nicks, etc.
- Thrust bearings for cracks and deformation; surfaces for smoothness and absence of scratches and nicks.
- Camshaft cams and cam faces for worn or deformed condition; journal surfaces and bearings for highly polished condition and absence of scratches, nicks, etc.; cam contours and cam followers for good condition.
- Connecting rods for cracks or other flaws by magnaflux or dye penetrant method and for bending and parallelism; bearings for highly polished condition and absence of scratches, nicks, cracks, and deformation.
- Pistons for cracks and warped condition; verify pistons, rings, and pins comply with manufacturer's requirements; rings and pins for general good condition.
- Timing gear mechanisms for good condition; backlash for manufacturer's tolerance requirements; gear teeth for general good condition.
- Auxiliary or accessory drives for good operating condition. Consult the specific manufacturer's literature for instructions.

A-1.1.6 Repair Parts and Supplies.

Certain repair parts and supplies must be available for immediate use. Refer to specific manufacturer's literature for recommendations. The following information is a general guide:

- The following parts should be renewed at each component change: gaskets, rubber sleeves, and seals. Adequate quantities should be maintained.
- The following parts have a reasonably predictable service life and require replacement at predictable periods: fuel injectors, pumps, governors, and valves. A one-year supply should be maintained.
- The following parts have a normally long life and, if failure occurs, could disable the engine for a long period of time: cylinder head, cylinder liner, piston and connecting rod, gear and chain drive parts, and oil pressure pump. One item of each part for an engine should be available.

A-1.1.7 Parts Salvage.

Certain parts may be replaced prior to their failure due to a preventive maintenance program. It may be possible to restore these parts to specified tolerances. Refer to specific manufacturer's literature for recommendations and instructions. The following information is a general guide:

- Worn pump shafts and cylinder liners may be built up and machined to specified dimensions.
- Grooves in pistons may be machined and install oversize rings specified for use.
- Press-fitted bushings and bearings may loosen. The related body part may be machined to a new dimension and oversize bushings and bearings fitted.
- Worn journals on crankshafts and camshafts may be built up and machined to specified dimensions.

A-2 GENERATOR MAINTENANCE.

A-2.1 Service and Troubleshooting.

Service consists of performing basic and preventive maintenance checks that are outlined in Table A-3. If troubles develop or if these actions do not correct a problem, refer to Table A-4. Maintenance personnel must remember that the manufacturer's literature supersedes the information provided herein.

A-2.2 Operational Check.

Check the equipment during operation and observe the following indications:

- Unusual noises or noisy operation may indicate excessive bearing wear or faulty bearing alignment. Shut down and investigate.
- Equipment overheats or smokes. Shut down and investigate.
- Equipment brushes spark frequently. Occasional sparking is normal but frequent sparking indicates dirty commutator and/or brush or brush spring defects. Shut down and investigate.

A-2.3 Preventive Maintenance.

Inspect the equipment as described once a month. Maintenance personnel should make a checklist suited to their particular needs. The actions listed in Table A-3 are provided as a guide and may be modified. Refer to manufacturer's instructions.

A-2.4 Troubleshooting.

Perform general troubleshooting of the equipment as outlined in Table A-4 if a problem develops. Table A-6 provides guidance on interpreting insulation test results and Table A-7 provides low voltage circuit breaker troubleshooting checks. Refer to the manufacturer's literature for repair information after diagnosis.

Table A-3 Generator Inspection Checklist

Inspect	Check For
Brushes	Amount of wear, improper wear, spring tension
Commutator	Dirt, amount of wear, loose leads, loose bars
Collector rings	Grooves or wear, dirt, carbon and/or copper accumulation, greenish coating (verdigris)
Insulation	Damaged insulation; measure and record insulation resistance
Windings	Dust and dirt, connections, loose windings or connections
Bearings	Loose shaft or excessive endplay, vibration (defective bearing)
Bearing housing	Lubricant leakage; dirt or sludge in oil (sleeve bearings)
Ventilation and cooling	Obstruction of air ducts or screens; loose or bent fan blades

Table A-4 Generator Troubleshooting

Cause	Remedy
NOISY OPERATION	
Unbalanced load or coupling	Balance load and check alignment misalignment
Air gap not uniform	Center rotor by replacing or shimming bearings
Coupling loose	Tighten coupling
OVERHEATING	
Electrical load unbalanced	Balance load
Open line fuse	Replace line fuse
Restricted ventilation	Clean; remove obstructions
Rotor winding shorted, opened, or grounded	Repair or replace defective coil

Cause	Remedy
Stator winding shorted, opened, or grounded	Repair or replace defective coil
Dry bearings	Lubricate
Insufficient heat transfer of cooler	Verify design flow rate: repair or replace unit
NO OUTPUT VOLTAGE	
Stator coil open or shorted	Repair or replace coil
Rotor coils open or shorted	Repair or replace coils
Restricted ventilation	Clean; remove obstructions
Shorted slip rings	Repair as directed by manufacturer
Internal moisture	Dry winding (indicated by low-resistance reading on megger)
Voltmeter defective	Replace
Ammeter shunt open	Replace ammeter and shunt
OUTPUT VOLTAGE UNSTEADY	
Poor commutation	Clean slip rings and reseat brushes
Loose terminal	Clean and tighten all contact connections
Fluctuating load	Adjust voltage regulator and governor speed
OUTPUT VOLTAGE TOO HIGH	
Over-excited	Adjust voltage regulator
One leg of delta-connected stator open	Replace or repair defective coils
FREQUENCY INCORRECT OR FLUCTUATING	
Speed incorrect or fluctuating	Adjust speed-governing device
VOLTAGE HUNTING	
External field resistance in out position	Adjust resistance
Voltage regulator contacts dirty	Clean and reseat contacts
STATOR OVERHEATS IN SPOTS	
Open phase winding	Cut open coil out of circuit and replace at first opportunity; cut and replace the same coil from other phases
Rotor not centered	Realign and replace bearings, if necessary

Cause	Remedy
Unbalanced circuits	Balance circuits
Loose connections or wrong connections	Tighten connections or correct wrong polarity coil connections
Shorted coil	Cut coil out of circuit and replace at first opportunity
FIELD OVERHEATING	
Shorted field coil	Replace or repair
Improper ventilation	Remove ducts obstruction, clean air filter
ALTERNATOR PRODUCES SHOCK WHEN TOUCHED	
Reversed field coil.	Check polarity. Change coil leads.
Static charge.	High-speed charge belts build up a static. Connect alternator ground strip frame to a ground strip.

Table A-5 Interpreting Insulation Resistance Test Results

Test Results Condition	What to Do
Fair to high values and well-maintained	No cause for concern
Fair to high values but showing a constant tendency towards lower values	Locate and remedy the cause then check the downward trend
Low but well-maintained	Condition is probably all right, but cause of low values should be checked
So low as to be unsafe	Clean, dry out, or otherwise raise the values before placing equipment in service (test wet equipment while drying out)
Fair or high values, previously well-maintained but showing sudden lowering	Make tests at frequent intervals until the cause of low values is located and remedied; or until the values have become steady at a lower level but safe for operation; or until values become so low that it is unsafe to keep the equipment in operation

Table A-6 Condition of Insulation Indicated Absorption Ratios by Dielectric Insulation

Insulation	60/30-Second Ratio	10/1 - Minute Polarization Ratio Index
Dangerous	--	Less than 1
Questionable	1.0 to 1.25	1.0 to 2
Good	1.4 to 1.6	2 to 4
Excellent	Above 1.6	Above 4

Table A-7 Low Voltage Circuit Breaker Troubleshooting

Issue	
Cause	**Remedy**
Note: Refer to manufacturer's literature for specific information on circuit breakers.	
OVERHEATING	
Contacts not aligned	Adjust contacts
Contacts dirty, greasy, or coated with dark film	Clean contacts
Contacts badly burned or pitted	Replace contacts
Current-carrying surfaces dirty	Clean surfaces of current-carrying parts
Corrosive atmosphere	Relocate or provide adequate enclosure
Insufficient bus or cable capacity	Increase capacity of bus or cable
Bolts and nuts at terminal connections not tight	Tighten but do not exceed elastic limit of bolts or fittings
Current in excess of breaker rating	Check breaker applications or modify circuit by decreasing load
Inductive heating	Correct bus or cable arrangement
FAILURE TO TRIP	
Travel of tripping device does not provide positive release of tripping latch.	Adjust or replace tripping device.
Worn or damaged trip unit	Replace trip unit
Mechanical binding in overcurrent trip device	Correct binding condition or replace overcurrent trip device

Issue	
Cause	**Remedy**
Electrical connectors for power sensor loose	Tighten, connect, or replace electrical connectors
Loose or broken power sensor connections	Tighten or re-connect tap coil tap connections
FALSE TRIPPING	
Overcurrent pick-up too low	Check application of overcurrent trip device
Overcurrent time setting too short	Check application of overcurrent trip device
Mechanical binding in over condition current trip device	Correct binding or replace overcurrent trip device
Captive thumbscrew on power sensor loose. Fail safe circuitry reverts characteristics to minimum setting and maximum time delay.	Adjust power sensor. Tighten thumbscrew on desired setting.
Ground sensor coil improperly connected	Check polarity of connections to coil. Check continuity of shield and conductors connecting the external ground sensor coil.
FAILURE TO CLOSE AND LATCH	
Binding in attachments preventing resetting of latch	Realign and adjust attachments
Latch out of adjustment	Adjust latch
Latch return spring too weak or broken	Replace spring
Hardened or gummy lubricant	Clean bearing and latch surfaces
Safety pin left in push rod	Remove safety pin
Motor burned out	Replace motor
Faulty control circuit component	Replace or adjust faulty device
BURNED MAIN CONTACTS	
Improper contact sequence (main not sufficiently parted when arcing contacts part)	Increase arcing contact wipe. Adjust contacts contact opening sequence. Refer to manufacturer’s literature for contact maintenance and adjustment information.
Short-circuit current level above interrupting rating of breaker	Requires system study and possible replacement with breaker having adequate interrupting capacity.

A-3 MEDIUM-VOLTAGE ELEMENTS.

A-3.1 Troubleshooting.

Use recognized industrial practices as the general guide for servicing. Refer to manufacturer's literature for specific information on individual voltage regulators. Troubleshooting procedures include the following: (a) check voltage for compliance with manufacturer's specifications, and (b) check for loose or insecure electrical connections.

A-3.2 Switchgear Equipment Troubleshooting.

Use recognized industrial practices as the general guide for servicing. Refer to manufacturer's literature for specific information on individual voltage regulators.

Troubleshooting procedures include the following:

- Check voltage for compliance with manufacturer's specifications.
- Check for loose or insecure electrical connections.
- Check for correct setting; refer to manufacturer's literature.
- Check for unregulated voltage; refer to manufacturer's literature.
- Check the enclosure; should be weather-tight.
- Check motor for proper operation and loose connections. Clean and lubricate as required. Refer to manufacturer's literature for details.
- Voltage regulators and associated equipment are normally mounted within switchgear equipment and are interconnected with different components. The proper operation and troubleshooting of voltage regulator equipment can depend on these different components. Perform the procedures in Table A-8.

Table A-8 Switchgear Equipment Troubleshooting

Issue	
Cause	**Remedy**
Note: Refer to manufacturer's literature for specific information on individual equipment.	
WATTHOUR METER INACCURATE	
Meter may be dirty or damaged	Install new meter, return faulty meter to repair depot for repair and calibration.
Faulty wiring or connections	Inspect and repair as necessary.
WATTHOUR METER FAILS TO REGISTER	
Blown potential transformer fuse, wiring broken wires, or other fault in connections	Renew blown fuses. Check and repair as required.
Wedge or block accidently left at time of test or inspection	Remove wedge or block. Verify that meter is in good operating condition.
DAMAGED CONTROL, INSTRUMENT TRANSFER SWITCH, OR TEST BLOCKS	
Burned or pitted contacts	Dress or clean burned contacts or replace with new contacts if necessary.
RELAYS FAILING TO TRIP BREAKERS	
Improper setting	Adjust setting to correspond with circuit conditions. Refer to manufacturer's instructions.
Dirty, corroded, or tarnished contacts	Clean contact with knife or tile. Do not use emery cloth or sandpaper.
RELAYS FAILING TO TRIP BREAKERS	
Contacts improperly adjusted	Adjust contacts. Verify proper wipe action.
Open or short circuit connections	Check to verify that voltage is applied and current is passing through relay in question.
Improper application of target	Verify proper tripping action of target and holding coil.
Faulty or improperly adjusted timing devices	If timing device is of bellows or oil-film type, clean and adjust. If an induction-disk type, check for mechanical interference. Refer to manufacturer's literature.
NOISES DUE TO VIBRATING PARTS	
Loose bolts or nuts permitting excessive vibration	Tighten to proper torque value.

Issue	
Cause	**Remedy**
Loose laminations in cores of transformers, reactors, etc.	Tighten loose nuts or core clamps to proper torque value.
CONNECTIONS OVERHEATING	
Increase of current due to overload conditions	Increase the carrying capacity (increase the number or size of conductors). Remove excess current.
Connecting bolts and nuts not tight	Tighten ail bolts and nuts to proper torque value.
FAILURE IN FUNCTION OF ALL INSTRUMENTS AND DEVICES HAVING POTENTIAL WINDINGS	
Loose nuts, binding screws, or broken wire at terminals	Tighten all loose connections to proper torque value or repair broken wire circuits.
Blown fuse in potential transformer circuit	Renew blown fuses.
Open circuit in potential transformer primary or secondary circuits	Repair open circuit and check entire circuit for continuity and good condition.
BREAKER FAILS TO TRIP	
Mechanism binding or sticking	**\1** Lubricate breaker mechanism; refer to manufacturer's instructions. **/1/**
Mechanism out of adjustment	Adjust all mechanical devices (toggles, stops, buffers, opening springs, etc.) according to manufacturer's instructions.
Failure of latching device	Examine surface of latch; replace latch if worn or corroded. Check latch wipe; adjust according to manufacturer's instructions.
Damaged trip coil	Replace damaged coil.
Blown fuse in control circuit (where trip coils are potential type)	Replace blown fuse.
Faulty connections (loose or broken wire) in trip circuit	Repair faulty wiring; tighten all binding screws to proper torque value.
OIL CONTAMINATED	
Carbonization from too many operations	Drain oil and filter; clean or replace. Add fresh oil. Clean inside of tank and all internal parts of breaker; refer to manufacturer's instructions.
Condensation due to atmospheric conditions	Same procedure as above.
Overheating	Eliminate cause of overheating.

Issue	
Cause	**Remedy**
RELAY TROUBLESHOOTING	
Note: Refer to manufacturer's literature for specific information on individual equipment.	
MAGNET-OPERATED INSTANTANEOUS TYPE	
High Trip Action	
Faulty coil	Install coil with correct rating.
Low Trip Action	
Shorted turns on high trip	Test coil and replace with new coil if found defective.
Mechanical binding; dirt, corrosion	Clean parts.
Assembled incorrectly	See manufacturer's instructions.
MAGNET-OPERATED INVERSE-TIME TYPE	
Slow Action Trip	
Fluid too heavy, vent too small, or temperature too low	Change fluid and open vent slightly; regulate temperature.
Worn parts	Replace and adjust.
Fast Trip Action	
Worn, broken parts	Replace and adjust.
Fluid too light, vent too large, or temperature too high	Change fluid to proper grade. Close vent slightly or regulate temperature. Clean dashpots and refill with fresh fluid or proper grade.
THERMAL TYPE	
Fails to Trip, Causing Motor Burnout	
Wrong size heater	Check rating with recommendations on instruction sheet.
Mechanical binding; dirt, corrosion	Clean and adjust.
Relay damaged by short circuit	Replace relay.
Motor and relay in different ambient temperature	Install motor and control near each other or make temperature uniform for both.

A-3.3 Routine Maintenance.

Routine maintenance instructions for prime movers consist of short- and long-term checklists for diesel and gas turbine engines.

A-3.3.1 Diesel Engines Short-term Checklist.

Before performing any tasks required by Table A-9, review the station log sheets, related records, and manufacturer's recommendations.

Table A-9 Diesel Engines Short-Term Checklist

Item	Action
Valves	Check valve operation.
Fuel injection nozzles	Check fuel-injection nozzles for secure mounting and connections each time the engine is shut down. Torque down the nozzle according to the manufacturer's instructions.
Starting system	Check the general condition of the air compressor, air lines, and valves, when applicable. Briefly open the system's safety valve weekly. Check for proper operation. Refer to manufacturer's instructions for details.
Governor alarms and instruments	Check operation of governor alarms and instruments. Refer to manufacturer's instructions.
Pressure gauges	Check pressure gauges and clean exposed indicating elements. Refer to manufacturer's instructions.
Intake and exhaust systems	Check air filters and engine exhaust. A smoking exhaust indicates incorrect adjustments. Clean air filters as necessary.
Exhaust lines	Clean and inspect exhaust lines. On two-cycle engines, remove carbon from exhaust ports and clean thermocouples. Refer to manufacturer's instructions for frequency of checks.

Item	Action
Evaporative cooling	Refer to manufacturer's instructions for cooling tower maintenance. Inspect and oil fan shaft bearings, oil damper bearings, and linkage. Inspect spray nozzles; clean as necessary. Clean pump suction screen. Clean sump pan. Inspect cooling coil. If scale has formed, circulate cleaning solution. Do not operate fan while cleaning coil. Check belts for condition and proper tension. Refer to manufacturer's instructions.
Fuel oil system	Clean fuel oil strainers as required by operating conditions. Check the system components for clean condition. Refer to manufacturer's recommendations.
Fuel filters and centrifuges	Check fuel oil filters and centrifuges. Check fuel oil system for leaks and correct as required. Refer to manufacturer's instructions.
Lubricating systems	Check mechanical lubrication hourly during operation. Oil all hand lubrication points, following manufacturer's instructions. Correct leaks.
Sight-feed lubricators	Clean sight-feed lubricating oil strainers as necessary. Check for adequate lubricant supply.
Lubricating oil filters	Check lubricating oil filters. Clean and replace filter elements as necessary.
Piston assembly and connecting rods	On two-cycle engines, remove upper handhole inspection cover from side of engine immediately after the engine is shut down and inspect the piston for proper lubrication.
Cylinders and cylinder heads	Use compressed air to blow out indicator connections. Clean indicators and install. Refer to manufacturer's instructions.
Crankshaft, crankpin and main bearings	Remove crankcase covers immediately after engine is shut down. Check main and crankpin bearings for proper lubrication. Check bearing temperatures for excessive heat by hand-touch. Refer to manufacturer's instructions for frequency of checks.

Item	Action
Gauges and instruments	Verify that gauges and instruments have up-to-date calibration certifications. Read and record all indications of gauges, thermometers, and other instruments at regular intervals as required by the operating log.
Turbocharger	Observe every four hours during operation. Check for general condition and signs of vibration. Evaluate vibration if present.
Turbocharger impeller	Check turbocharger impeller for accumulated dirt and axial endplay. Dirt may indicate faulty filtering equipment. Clean and service according to manufacturer's instructions.

A-3.4 Diesel Engines Long-Term Checklist.

Performance of checklist tasks is related to frequency and extent of use of the auxiliary power plant. Table A-10 tasks should be performed annually unless otherwise noted, following performance of short-term checks.

Table A-10 Long-Term Checklist for Diesel Engines

Item	Action
Valve inspection	Inspect exhaust valves; clean and remove carbon on two-cycle engines and valves as necessary. Refer to manufacturer's instructions.
Inlet valves	Inspect and regrind inlet and exhaust valves and valve seats as necessary. Refer to manufacturer's instructions.
Valve springs and guides	Check valve spring length and tension and inspect valve stems, bushings, and guides annually or after 2,000 hours of use, whichever comes first. Replace parts as necessary. Refer to manufacturer's instructions.
Camshaft and drive	Check and adjust gears and/or timing chain. Refer to manufacturer's instructions.
Camshaft bearings	Inspect and adjust camshaft bearing clearances. Refer to manufacturer's instructions.

Item	Action
Fuel injection nozzle inspection	After 2,000 hours of use, remove and check nozzles in the test stand. Service and adjust nozzles following manufacturer's instructions.
Fuel injection pumps	Inspect fuel injection pumps for secure mounting, cleanliness, and proper operation.
Fuel injection pump inspection	Disassemble and recondition all injection pump nozzles after 2,000 hours of use. Repair or replace worn or damaged parts. Reassemble and adjust, following the manufacturer's instructions.
Air lines	Drain water from air lines and tank monthly or as necessary. Drain valves are usually located at the lowest point(s) in the air feed system.
Air valves	Clean air valves and reseat if necessary. Refer to manufacturer's instructions.
Air compressor	Disassemble and overhaul air compressor and starting equipment every five years based on frequency of use of the auxiliary power plant.
Pressure gauge inspection	Check the date of calibration. Verify that gauges have valid calibration certification. Calibrate per manufacturer's instructions as required.
Governor overhaul	Overhaul the governor after 2,000 hours of use or when needed, as indicated. Repair or replace worn or damaged parts. Reassemble and adjust, following the manufacturer's instructions.
Muffler (silencer)	Keep the muffler and waste heat equipment, boiler, or heat exchange clean. Accumulations of unburned lubricating oil and soot or carbon are potential fire hazards. Make sure fuel combustion is as efficient as possible. Refer to manufacturer's instructions.
Cooling systems	Inspect piping and valves for leaks and clean the heat exchanger. Perform cooling system maintenance; refer to manufacturer's instructions.
Cooling tower	Drain and clean cooling tower; clean and inspect piping, circulating pumps, and equipment.

Item	Action
Cooling system service	Clean and inspect entire cooling system yearly. Overhaul pumps and recondition valves and other equipment as necessary. Refer to manufacturer's instructions.
Fuel oil tanks and lines	Drain service tanks and lines. Remove water and sediment. Check heating coil for proper operation.
Lubricating oil cooler	Clean and inspect lubricating oil cooler for leaks and good condition. Clean outer surfaces more often under dusty operating conditions for more efficient cooling. Refer to manufacturer's instructions.
Crankcase	Drain crankcase semiannually or more frequently based on number of hours run per manufacturer's recommendations or acceptable industrial engine maintenance procedures. Inspect lubricating oil pumps; flush crankcase and refill. **\1** Refer to manufacturer's instructions and, for Army, PAM 750-8, *The Army Maintenance Management System (TAMMS) User's Manual*. **/1/**
Lubricating oil pump	Inspect the pump after 2,000 hours of use for proper operation. Refer to manufacturer's specifications for the pump.
Cylinder heads	Remove cylinder heads according to manufacturer's instructions after 2,000 hours of use. Inspect cylinder liners. Clean and inspect water jackets. Remove scale and corrosion as necessary. Inspect and measure diameter of cylinder liners. Check gaskets for annealing, brittleness, or cracks. Install new gaskets if necessary.
Piston assembly inspection	On four-cycle engines, pull one piston after 2,000 hours of use and inspect for proper cooling, lubrication, and carbon deposits. Inspect piston rings and wrist pin and the cylinder liner for compliance with engine manufacturer's specifications.
Pistons inspection	Pull pistons after 4,000 hours of engine use. Clean and inspect all parts for wear, proper lubrication, and cooling. Verify that rings and ring clearances comply with engine manufacturer's specifications.

Item	Action
Cylinder inspection	Use the barring device (jacking bar) to turn each piston to top dead center during inspection. Inspect each cylinder liner for scoring. Refer to manufacturer's instructions.
Anchor bolts	Check anchor bolts for proper torque value.
Flywheel bolts	Check flywheel bolts for proper torque value. Refer to manufacturer's instructions. Verify alignment and coupling to generator; comply with specifications.
Main and crankpin bearings	Remove bearing caps; check journals and bearings for proper lubrication, wear, or scoring. Check main bearings for proper alignment. Refer to manufacturer's instructions.
Crankshaft	Verify compliance with engine manufacturer's specifications. Examine crankshaft for cracks. Measure distance between crank webs for crankshaft deflection. Check journal level and clean oil passages. Replace bearings as necessary and adjust running clearance, following the manufacturer's instructions.
Turbocharger inspection	Disassemble, clean, and inspect entire turbocharger following manufacturer's instructions and specifications.
General overhaul	Overhaul diesel engines and driven equipment every ten years or about 16,000 hours of auxiliary use. Follow the manufacturer's recommendations and instructions. Comply with the manufacturer's specifications.

A-3.5 Short-Term Checklist for Gas Turbines.

Checks are limited to inspection and cleaning tasks that can be performed on the exterior of an engine.

A-3.5.1 General.

Before performing any tasks required by the following checklist, review the station log sheets, related records, and the manufacturer's recommendations. The following precautions must be met.

- Shut the engine down.
- Apply "Do not operate" tags to the operating controls.

- Open the engine automatic start circuit.
- Deactivate the fire extinguishing system.
- Keep all engine enclosure doors open while working on the engine.
- Allow engine to cool down before working on it.

A-3.5.2 Short-Term Checklist.

Table A-11 provides a short-term checklist for gas turbines.

Table A-11 Gas Turbine Short-Term Checklist

Item	Action
Inlet inspection	Verify the inlet drain at lower part of duct is open and free of any obstruction so moisture (rain or condensation) can run off. Check inlet temperature sensor for signs of damage. Clean sensor and surrounding area with approved solvent to remove dirt and contaminants. Refer to manufacturer's instructions. Make sure sensor is securely attached to engine.
Exhaust Inspection	Visually inspect engine exhaust casing, struts, and center body for cracks, nicks, and other signs of damage. Refer to manufacturer's instructions. Inspect exhaust stack for freedom from obstructions and general good condition
Chip Detectors	Engines usually have plugs with magnetic chip detectors at lubrication sumps. During normal operation, some fuzz-like particles will be found on the detectors. Also, other materials (non-metallic sludge and/or flakes, bronze powder, aluminum chips, etc.) may accumulate on the plugs. Refer to manufacturer's literature for specific information. Check chip detectors for electrical continuity while installed. Continuity is an indication of contamination. Remove chip detectors if contaminated. Discard packing and clean chip detector. Check chip detector for good thread and proper magnetism. Place new packings on chip detectors and install on engine. Tighten to proper torque.

Item	Action
External Inspection	Inspect engine tubes, hoses, tube/hose fittings, electrical assemblies and connectors for security, and overheating and damage due to leakage. Perform inlet and exhaust inspection as previously described. Check standoffs, brackets, and struts for looseness, cracks, and damage. Check ignition exciter, igniter plugs and leads for damage, overheating, and security. Check mechanical control for signs of excessive wear, damage, and security. Check fuel manifold for leaks, signs of damage, and security. Check for rust and/or corrosion.

A-3.6 Long-Term Checklist for Gas Turbines.

Long-term checks usually affect interior areas of the engine and are seldom performed in the field. Repairs, if necessary, may involve changes in component balance relationships and should be performed at the designated overhaul location. Refer to the manufacturer's literature for information.

A-4 GENERATORS AND EXCITERS.

Routine maintenance instructions for generators and exciters consist of short- and long-term checklists for rotating and static type equipment.

A-4.1 Short-term Checklist.

Before performing any Table A-12 tasks, review the station log sheets, related records, and the manufacturer's recommendations.

Table A-12 Generators and Exciters Short-Term Checklist

Item	Action
Air screens or filters	Air screens or filters should be changed when the air flow is restricted enough to increase generator operating temperature. Refer to manufacturer's literature.
Exciter coupling (if applicable)	When generator unit is shut down prior to operation, wipe off excess lubrication from the coupling to prevent spatter.
Coupling leaks and alignment	When generator has been shut down, check for lubrication leaks and tightness of coupling. Note any evidence of improper alignment and correct if necessary.
Axial position	Check axial position of the prime mover, generator, and exciter shafts for correct alignment and angularity.
Bearings	Lubrication of generator and exciter bearings is required. Refer to manufacturer's literature for instructions for pressure and non-pressure lubricated bearings.
Rotary exciters, brushes, and brush rigging	Remove carbon dust from collector ring and commutator with vacuum and dry with compressed air at about 25 psi (172 kPa) monthly. Check brushes for wear and indications of arcing and chattering monthly. Check condition of slip rings. Refer to manufacturer's instructions.
Static exciters	Verify the equipment is clean and free from dirt and moisture. Verify all connections are tight. Check connections for corrosion and clean as required.

A-4.2 Long-term Checklist.

Table A-13 tasks should be performed annually unless otherwise noted in manufacturer's instructions, and following execution of short-term checks.

Table A-13 Generators and Exciters Long-Term Checklist

Item	Action
Coupling lubrication	Drain lubricant, disassemble, and clean coupling annually or whenever necessary. Reassemble, using new gaskets and fresh lubricant. Refer to manufacturer's instructions for flexible coupling.
Brush replacement	When brushes have worn to half their original length, replace, seat properly, and adjust brush rigging tension from 2.5 to 3.6 psi (17.2 to 24.8 kPa) on brush riding surface. Repair and replace damaged or worn brush rigging parts. Refer to manufacturer's instructions.
Brush electrolysis	Electrolytic action can occur at collector ring surfaces. This action forms a greenish coating (verdigris) on brass, bronze, or copper. Effects of this action can be reduced or eliminated by reversing the polarity annually or as required. Refer to manufacturer's instructions.
Commutator and collector rings	Clean commutator and collector rings with vacuum. Clean oil film and dirt with approved solvent. Dry with compressed air at about 25 psi (172 kPa). Check for roughness, hard spots, and out-of-round condition. Service commutator and collector rings as necessary, following manufacturer's instructions.
Rotor winding	Rotor maintenance begins with measuring and recording the insulation resistance before the unit is placed in service. Refer to manufacturer's literature for instructions. The rotor should be thoroughly cleaned annually and inspected as follows: • Check the damper winding for loose bars and the connection of each bar to its ring segment. • Check the joints in the ring segments between poles. Refer to manufacturer's instructions. • Check clearance per manufacturer's specifications between blower and coils.

Item	Action
	• Check the field coils for movement and separation. • Clean dirt and oil from winding and air passages. • Check condition of turn-to-turn insulation on strap field coils. • Verify condition of ground insulation on pole pieces. • Check all connections between field coils and lead-out connections to collector rings. • Measure and record insulation resistance between field coils and ground, including the collector rings. Refer to manufacturer's instructions. • Check bearings and journals for damage or excessive wear. • Compare micrometer readings with the manufacturer's table of wear limits. • Repair or replace mechanical parts to meet these specifications. • Dry out according to manufacturer's instructions. • Repair insulation damage and coat with approved insulating varnish.
Rotor balancing	Measure and record vibration limits of repaired unit when it is started. Refer to manufacturer's specifications for vibration limits for the specific unit. Perform static or dynamic balancing of the unit, according to instructions, if necessary.
Stator winding	Measure and record insulation resistance between stator winding and ground at the machine terminals annually.
Stator service	Open up the stator annually. Clean thoroughly and inspect for the following: broken, damaged, loose, or missing wedges; movement or distortion of coil ends; security of all lashing and spacers; tightness of coil supports; cooling passages are open and clean; looseness of coils in slots; cracks or other damage to coil insulation; and connections between coils and around the frame. Measure and record insulation resistance between winding and ground at the machine terminals. Compare the values with those recorded when the machine was first put in service.

A-4.3 Checklist and Schedule for Solid-state Exciters.

Solid-state equipment does not require long-term checks. If the equipment does not function properly, refer to the manufacturer's literature for information. Repair or replace as required.

A-5 SWITCHGEAR MAINTENANCE.

Routine maintenance instructions for switchgear consist of short- and long-term checklists. De-energize switchgear before performing maintenance. Disconnect primary and secondary sources of power.

A-5.1 Short-Term Checklist.

Before performing any tasks in Table A-14, review the station log sheets, related records, manufacturer's recommendations, and NFPA 70E.

Table A-14 Switchgear Maintenance Short-Term Checklist

Item	Action
Panels and other exterior surfaces	Panels and exterior surfaces must be kept scrupulously clean at all times.
Relays and actuating mechanisms	Clean and inspect relays and actuating mechanisms monthly. Many types of relays are used. Identify the relays such as thermal, current overload, over speed, liquid level, lubricating oil pressure and/or flow, frequency change, etc. Refer to manufacturer's literature for inspection procedures. Verify all connections are tight and free of corrosion.
Conductors and coils	Clean and inspect conductors and coils monthly. Verify coating of insulating varnish is in good condition (clean, smooth, and polished) and there are no indications of overheating or corona arcing.
Switches	Inspect switches for proper alignment, firm contacts, and smooth operation monthly. Burned or pitted copper contact surfaces may be dressed with 2/O sandpaper. Do not dress silver contacts.
Circuit breakers	Trip and close circuit breakers; check for proper operation quarterly. Check time delay and freedom of movement. Refer to manufacturer's instructions.
Coils and heaters	Check coils and heaters quarterly for secure mounting and circuit continuity. Check controls and thermostats for proper operation; refer to manufacturer's instructions.
Contactors	Check magnet surfaces of contactors quarterly for cleanliness. Remove gum, rust, or corrosion. Adjust for even contact pressure according to manufacturer's instructions.
Voltage regulators	Check voltage regulators for proper operation and adjustments quarterly. Various makes and types are used. Refer to manufacturer's literature for instructions.

A-5.2 Long-term Checklist.

Performance of tasks is related to frequency and extent of use of the auxiliary power plant. Table A-15 tasks should be performed annually unless otherwise noted in manufacturer's guidance and following the execution of short-term checks. The procedures are general but apply primarily to draw-out equipment.

Before performing any tasks required by the following checklist, review the station log sheets, related records, manufacturer's recommendations, and NFPA 70E.

Table A-15 Switchgear Maintenance Long-Term Checklist

Item	Action
Panels and other exterior surfaces	Panels and exterior surfaces must be kept clean at all times.
Meters and instruments	Check meters and instruments against a verified standard. Return defective or inaccurate meters and instruments to the manufacturer or designated repair location for service and calibration.
Buses	Inspect buses and connections for signs of overheating or weakening of insulating supports. Overheating is indicated by discoloration of the bus bar. Inspect insulators for cracks and/or arc tracks. Replace defective insulators. Tighten bus bar and terminal connections to the proper torque value.
Indicating devices and interlocks	Check indicating devices and interlocks for proper operation. Refer to manufacturer's instructions.
Disconnecting devices	Check primary disconnecting device contacts for signs of overheating or abnormal wear. Clean contacts with silver polish. Clean disconnecting device contacts and apply light coating of approved lubricant.
Enclosure	Verify that interior anchor bolts and structural bolts are tight. Inspect cable connections for signs of overheating. Tighten loose connections as required.
Circuit breakers	Manually operate each breaker while in test position; verify proper operation. Refer to manufacturer's instructions.

Item	Action
Environmental conditions	More frequent inspections of the switchgear must be made when unusual service conditions exist, such as contaminating fumes, excessive moisture, or extreme heat or cold. Additional protection may be required if adverse conditions are present.
Ground resistance	Measure and record ground resistance values using a ground resistance test set. Compare these values with those recorded during previous tests. The tests indicate grounding system effectiveness and possible deterioration since the last tests.

A-6 OIL MAINTENANCE PROCEDURES.

Table A-16 provides a general guide for maintenance of lubricating oil. Table A-17 provides normal and maximum oil quality standards.

Table A-16 Oil Maintenance

Item	Action
Water and sediment	Clean by centrifuging.
Viscosity	Treat with oil reclaimer to drive off dilution. Centrifuge (hot) to remove heavy sludge. If necessary, add straight run mineral oil of lower viscosity.
Corrosion	Treat with activated-type reclaimer. If an additive oil is in use, the presence of corrosive qualities indicates the additive is exhausted. New oil must be used if the benefit of additives is required. Used oil may be reclaimed and used for other services not requiring the additive.
Particles	Passage of particles larger than the filter's specifications are a definite sign of channeling or structural damage to filter elements. Replace filter cartridges.

Table A-17 Oil Quality Standards

Item	Normal	Maximum
Water and sediment	1.0%	5.0%
Water	0.5%	3.0%
Sediment	0.5%	2.0%
Viscosity	±5%	±10%
Corrosion (copper strip)	None	Dull
pH	7% or higher	6.8%
Filtered particles (% of total residue)		
Larger than oil filter	None	2%
Metallic under 1 micron	Few	1%
Over 5 microns	None	1%

A-7 FUEL AND FUEL STORAGE.

A-7.1 Diesel Fuel.

Diesel fuel should comply with Federal Specifications W-F-800 MIL-F-16884, or specifications for JP-8. These specifications include grades DF-A, DF-1, DF-2, or types I and II. All are suitable for use under applicable temperature and service conditions. Different grades of fuel should not be mixed.

\1\ Note: For Air Force, see paragraph 8-6.3. **/1/**

A-7.1.1 Cleanliness.

Fuel must be clean. All dirt, dust, water, sediment, and other contaminants must be kept out of the fuel to prevent damage to engine fuel injection equipment. The specified grade of clean fuel must be used to ensure long, economical engine operation. Handling of fuel must be reduced to a minimum to avoid entry of contaminants. Delivery of fuel to storage tanks and then pumping it directly to the day tank through filters is a recommended procedure. Filters must be installed in all engine fuel lines and must be cleaned as recommended by the engine manufacturer.

A-7.1.2 Contamination.

Stored fuel and fuel storage systems must be inspected at regular intervals at a minimum of every 90 days. **\1** Consult T.O. 42B-1-1 for additional information on fuel contamination, testing, and quality surveillance. **/1/** Samples for detecting fuel contaminations are as follows:

1) Inspect fuel filters for indication of microorganism growth, rust, scale, or sediment. In a glass jar, collect a sample of diesel fuel from the bottom of the tank. Solid contaminants will settle and collect at the bottom of the jar. Clean the filters as directed by manufacturer's instructions.

2) Detect water in diesel fuel by collecting in a glass jar a sample of fuel from the bottom of the tank. Fuel and water will separate when the sample is allowed to settle, water will sink to the bottom of the jar. Fuel with water in it may appear white and cloudy when agitated.

3) Detect gasoline or kerosene in diesel fuel by collecting a sample (see above). Fuel and contaminants will separate when the sample is allowed to settle; the gasoline or kerosene will float on the fuel.

4) Detect oil-soluble soaps in diesel fuel by having an appropriate laboratory test performed. Avoid this kind of contamination; do not use galvanized storage tanks or piping.

5) Prevent condensation within storage tanks by keeping the tanks full. Tanks must be kept full during cold weather.

A-7.1.3 Storage.

Fuel tanks used for storage must have drain valves for removal of bottom water (to be done once every six months). Deterioration of stored fuel is caused by three factors: oxidation, microorganism contamination, and corrosion.

1) Oxidation occurs directly or through catalytic action. Oxygen from the air or fuel combines with fuel hydrocarbons, causing oxidation. Resultant oxidation continues as long as oxygen is present. Metals suspended in the fuel act as catalysts. Metals can enter the fuel during refining, distribution, or storage. The engine fuel system can thereby be damaged.

2) Microorganism contamination is caused by bacteria and fungus that exist in the bottom water. Waste by-products of the microorganisms form a self-sustaining corrosive environment. The byproducts can form a gelatinous mass that plugs fuel lines and filters and forms a fuel sludge, thereby reducing engine efficiency and possibly damaging the engine.

3) Corrosion of the storage tank does not directly deteriorate the fuel. Corrosion can destroy a metal storage tank, usually at the bottom. Metals that enter the fuel act chemically to speed up oxidation. The combination of microorganism growth and water causes oxidation.

A-7.2 Gas Turbine Fuel.

\1 Fuel for gas turbines consists of natural gas or light distillate oil such as kerosene, military jet engine fuel (JP-8, JP-5, TS-1, F-24), or commercial jet engine fuel (Jet A, Jet A-1). All are suitable for use under applicable temperature and service conditions. Most gas turbines can burn fuels used by diesel engines. Gas and oil fuels should not be mixed. Consult T.O. 42B-1-1 for additional information. **/1/**

A-7.2.1 Cleanliness.

Fuel must be clean. All dirt, dust, water, sediment, and other contaminants must be kept out of fuel to prevent damage to engine components. Only the specified grade of clean fuel should be used to ensure reliable engine operation. Handling of fuel must be reduced to a minimum to avoid entry of contaminants. Natural gas should be passed through several fine screen filters to remove solid particles and water vapor before it is fed to the gas turbine engine.

A-7.2.2 Contamination.

Stored fuel and fuel storage systems must be inspected at regular intervals at a minimum of every 90 days. Perform the following checks when cleaning filters for a natural gas system.

- Inspect the solid particles removed by fine screen filters. Determine if the particles are dust or dirt, or the type of metal if metallic.
- Inspect water accumulation for acid or alkaline content.

A-7.3 Storage.

Information relating to storing natural gas fuel follows:

- Natural gas can be stored in low-pressure surface containers or high-pressure sub-surface containers and metal bottles.
- Liquefied natural gas can be stored in insulated metal tanks installed as sub-surface units.
- The type of storage employed for natural gas depends on plant requirements and fuel availability.

A-7.4 Fuel Storage Maintenance Procedures.

Provide the base engineer’s office with the reports and results of inspections performed. The base engineer will review this data and take appropriate corrective action, which may include any or all of the following:

- Add an antioxidant to prevent oxidation or “aging” of a fuel.
- Add a fungicide or biocide to destroy organisms present in the water beneath stored fuel.
- Add a metal deactivator because metals in fuel catalyze or speed up oxidation. Inhibitors that place an amine film on metal surfaces are available. Amines are organic compounds that neutralize an electrical charge in metals.

Note that any chemical or additive that is added to stored fuel must be approved by the EPA. Also, the base engineer's office should monitor the removal of bottom water from storage tanks.

A-8 LUBRICATING OIL.

A-8.1 Diesel Engine Oil.

\1 Lubricating oil for diesel engines should comply with specifications MIL-PRF-2104 and MIL-PRF-9000. Oil that complies with the specifications produces acceptable amounts of carbon residue during engine use and has acceptable pour, flash, and fire points. Straight mineral oil is the basic ingredient. Inhibitors or chemicals are added to the oil by the oil refiner to ensure compatibility with a range of engines operating under varying conditions. The user must observe recommendations by the engine manufacturer for specific types and grades of oil for optimum engine performance. **/1/**

A-8.1.1 Characteristics.

Engine lubrication requires selection of the proper oil. Refer to the engine manufacturer's instructions. Examples of required oil characteristics are as follows:

- Oil should have sufficient viscosity to prevent metal-to-metal contact. Oils with lower SAE numbers are lighter and flow more readily than oils with higher numbers. Heavier oils, those with higher SAE numbers, may cause sluggish operation and power loss.
- Oil should remain stable during use under changing temperatures and conditions for satisfactory service.
- Check the engine periodically, such as every six months, for accumulation of sludge in the engine filters and strainers and around valve springs. Refer to the engine manufacturer's literature for specific information.
- Oil must be free of water and sediment. Collect a sample of oil in a glass jar. Allow the sample to settle. Water and solid contaminants settle to the bottom of the jar.

A-8.1.2 Additives.

Straight mineral oil does not have detergent qualities; therefore, various compounds are added to the oil. These additives keep the engine clean by controlling varnish formation or resisting chemical changes to reduce oxidation. Other additives form a protective film against corrosive acids.

A-8.1.3 Mixing Oils.

Different refineries may use different types of additives or certain characteristics of the mineral oil may vary. Mixing types of oil may change the necessary detergent actions. To obtain maximum benefit from additive type oils, do not mix them with straight mineral

oil. Concentrations of the additives are reduced when detergent oils and straight oils are mixed.

A-8.1.4 Changing Oil.

Lubricating oil must be changed periodically. Refer to recommendations by the engine manufacturer to specific conditions, time intervals, and instructions. General oil change procedures are as follows:

- Operate the engine before draining old oil. Oil should be drained while warm and immediately after engine shutdown because contaminants are in suspension and will readily drain.
- Obtain a sample of the drained oil and deliver it to the base engineer for testing. Drained oil should be examined for fuel dilution, acidity, and presence of solids and other contaminants. Testing helps establish the overall condition of the engine and approximate frequency of need for oil changes.
- Observe the viscosity of drained oil. In diesel engines, oil viscosity increases during service due to the gradual oxidation of the oil. Viscosity decreases if fuel gets into the oil by passing the piston rings or through leaks.

A-8.1.5 Oil Analysis Program.

Personnel in the engineer's office and other cognizant personnel should refer to PAM 750-8, *The Army Maintenance Management System (TAMMS) User's Manual*, for sampling and analysis information. The analysis of periodic samples of the lubricating oil should report the character and amount of contaminants, wear-metals, and additives in the oil. However, some amounts of wear metals and contaminants will have been collected by the chip collectors, strainers, filters, separators of the system, and also as sludge. To secure the total picture it is necessary to analyze all such collected material to determine the total rate of increase/decrease of each. This will indicate what has occurred during the period between samples.

Log and use all such data to track trends that give warning of conditions that may result, if uncorrected, in major problems.

A-8.2 GAS TURBINE OIL.

\1 Lubricating oil for gas turbines should comply with specifications MIL-PRF-23699 or MIL-PRF-7808. Oil that complies with the specification can withstand the high temperatures encountered during engine operation. **/1/**

A-8.2.1 Additives.

Various compounds are added to mineral oil to provide the special characteristics required for use in gas turbines. The user must observe lubricating oil recommendations by the engine manufacturer for optimum engine performance.

A-8.2.2 Changing Oil.

Refer to the engine manufacturer's literature for recommendations related to specific conditions, time intervals, and instructions for changing the lubricating oil. An oil analysis program is usually recommended, including a spectrometric analysis of the metal particles. It is necessary to collect and evaluate data for type and quantity of engine wear-metals. Study of this data shows trends of engine wear and expected future reliability.

- Collect a sample of old oil when oil is drained from the engine storage tank. Examine the drain plug or valve, filter, and chip detector (if used) for metal particles. Save the particles for analysis.
- Deliver the drain oil sample and particles to the base engineer for tests and analysis. The presence of some particles in the drain oil is usually considered normal by the engine manufacturer.

A-8.3 Coolant.

\1 The coolant used in diesel engines typically consists of a mixture of ethylene glycol antifreeze, corrosion inhibitor, and fresh water. When the engine is used in an extremely cold area, such as Arctic regions, a special antifreeze mixture is used. Specifications related to the mixtures are as follows:

- Antifreeze, Ethylene glycol MIL-A-46153
- Specification for cooling system conditioner and inhibitor is MIL-C-10597
- Antifreeze, Ethylene glycol A-A-52624
- Antifreeze, Arctic-type A-A-52624
- 5 Inhibitor, Corrosion MIL-A-53009 or MIL-A-46153 **/1/**

A-8.3.1 Engine Water Treatment.

A-8.3.1.1 Acceptable Conditions.

In most modern diesel engines, the following cooling water conditions are acceptable:

- pH 8.5 to 10
- Chloride and sulfate 100 ppm
- Total dissolved solids 500 ppm
- Total hardness 200 ppm

A-8.3.1.2 Softened Water.

If possible, softened water should be used to reduce the total hardness level of the engine cooling loop. The use of softened water will increase engine performance by reducing the precipitation of calcium and magnesium at elevated temperature conditions, ensuring higher heat transfer rates.

A-8.3.1.3 Antifreeze.

Typical engine cooling systems incorporate antifreeze solutions that inhibit scale and protect the cooling system when temperatures are encountered below freezing. Ethylene glycol mixed with a corrosion inhibitor such as triazoles form an inhibiting film on metal surfaces that acts as a barrier to the corrosion process. Table A-18 concentrations should be utilized when adding glycol solutions to the engine cooling system.

A-8.3.1.4 Concentration.

The ethylene glycol concentration should exceed 30 percent. If more than 60 percent of solution is added, two effects will be realized: 1) a decrease in heat transfer rates, 2) a lowering of the system freeze protection.

A-8.3.2 Cooling System Maintenance.

Maintenance consists of periodically testing the antifreeze, inspecting the coolant for cleanliness, and flushing or cleaning the system with compound when necessary.

A-8.3.2.1 Testing Antifreeze.

Perform tests to verify freeze protection and reserve alkalinity:

- Test for freeze protection using the combination antifreeze and battery tester (stock number 6630-00-105-1418). Instructions for using the tester are included with it.
- Test for reserve alkalinity (corrosion protection) using the reserve alkalinity test kit (stock number 6630-00-169-1506).
- Cooling systems with freeze protection below -7 °F (-22 °C) that fail the reserve alkalinity test may be replenished with corrosion inhibitor (stock number 6850-00-753-4967). Replenishment is a one-time service. If the reserve alkalinity test is failed again, replace the coolant. If the system passes the test, record the date.

A-8.3.2.2 Inspecting Coolant.

Inspect the coolant visually for cleanliness. Obtain a coolant sample and place it in a clean glass container. After allowing about five minutes for settling, examine the sample for contamination (rust, foreign particles, and/or sediment). The sample may have some color (same color as original antifreeze) and should be clear.

Examine the sample to determine the type and quantity of contamination. Rust, a chemical combination of iron, water, and air, is frequently found. The presence of rubber particles usually indicates deterioration of hoses. Replacement hoses may be indicated. Sediment may be caused by impurities in the water used in the coolant. Contaminants in the coolant can clog a radiator or heat exchanger and cause engine and generator system breakdown.

A-8.3.2.3 Cleaning the System.

Clean the cooling system whenever the coolant is drained. Usually the system requires nothing more than a thorough flushing with fresh water. Refer to the engine manufacturer's literature for instructions. If any part of the system is rusted or partially clogged, it is necessary to use cooling system cleaning compound and conditioner, stock number 6850-00-598-7328. Do not use the compound as a routine maintenance procedure. Instructions for using the compound are included with it.

A-8.3.2.4 Filling the System.

Refer to the engine manufacturer's literature for instructions on filling the cooling system. This is applicable to either new systems or those just cleaned and serviced.

A-8.3.2.4.1 Ethylene Glycol Antifreeze.

Cooling system protection is required for all liquid cooled diesel engines. In areas where temperatures no lower than -55 °F (-48 °C) are expected, prepare a solution according to the information presented in Table A-18. When temperatures below freezing are not expected, use a weak solution such as 1 pint of ethylene glycol antifreeze for each gallon of solution for general protection against rust buildup and scale formation within the engine.

A-8.3.2.4.2 Arctic-Type Antifreeze.

Use arctic-type antifreeze in areas where temperatures below -55 °F (-48 °C) are expected. Do not dilute arctic-type antifreeze with water or inhibitor; it is ready for use as issued.

Table A-18 Antifreeze Solutions

Guide for Preparing Ethylene Glycol Antifreeze Solutions	
Lowest Estimated Temperature in Area	**Pints of Antifreeze Needed to Prepare 1 Gallon of Solution**
+20 °F (-7 °C)	1.50
+10 °F (-12 °C)	2.00
0 °F (-18 °C)	2.75
-10 °F (-23 °C)	3.25
-20 °F (-29 °C)	3.50
-30 °F (-34 °C)	4.00
-40 °F (-40 °C)	4.25
-50 °F (-46 °C)	4.50
-55 °F (-48 °C)	4.75

A-9 ATS MAINTENANCE.

The following ATS maintenance actions are recommended:

- Follow NFPA 110 for visual inspection and cleaning, specifically Annex A.
- De-energize the switchgear and the ATS.
- Bypass isolation ATS may remain energized only to rack out the automatic switch.
- Remove the arc chutes and pole covers. Consult the manufacturer's information for proper procedure. This step will allow visual inspection of the main and arcing contacts.
- Test and recalibrate all trip-sensing and time-delay functions in the switchgear. Depending on the manufacturer, the steps required will vary. The focus should be to verify and record what current settings are and ensure the current adjustments meet the customer's needs and expectations. If adjustments are necessary, the means to make and verify those adjustments need to be examined. For example, a voltage pick-up or dropout adjustment may require the use of a variable source, such as a variable ac transformer. The standby engine can be a source of variable frequency, etc. Refer to manufacturer’s recommendation.
- Vacuum the accumulated dust from the switchgear and accessory panels. Do not use air to blow out dirt.

- Inspect for moisture or signs of previous wetness or dripping.
- Clean grime with an approved solvent. Consult the manufacturer's recommendations.
- Inspect all insulating parts for cracks or discoloration due to excessive heat. Use infrared scan if available.
- Inspect all main arcing contacts for excessive erosion. Replace contacts if damaged.
- Inspect all main current-carrying contacts for pitting and discoloration due to excessive heat.
- Inspect all control relay contacts for excessive erosion and discoloration due to excessive heat. If damaged, replace.
- Manually operate the main transfer movement to check proper contact alignment, deflection, gap, and wiping action.
- Check all cable and control wire connections to the transfer switch control and sensing panel and other system components and tighten if necessary.
- Re-energize the switchgear and conduct a test by simulating a normal source failure.
- ATS must be operated monthly.
- Circuit breakers should be tested under simulated overload conditions every two years.
- Simulate a power outage without turning off the normal power.

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APPENDIX B REFERENCES

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29 CFR 1926, *Safety and Health Regulations for Construction*

40 CFR 1 through 1100, *Environmental Protection Agency*

50 CFR 13, *General Permit Procedures*

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AFTO Form 781A, *Maintenance Discrepancy and Work Document*

AFI 13-204V3, *Airfield Operations Procedures and Programs*

AFI 21-113, *Air Force Metrology and Calibration (AFMETCAL) Management*

AFI 23-201, *Fuels Management*

AFI 23-204, *Organizational Fuel Tanks*

AFI 32-1001, *Operations Management*

AFI 32-1062, *Electrical Systems, Power Plants and Generators*

AFI 32-1064, *Electrical Safe Practices*

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AFI 32-7044, *Storage Tank Environmental Compliance*

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TB 43-180, *Calibration and Repair Requirements for the Maintenance of Army Materiel*, https://armypubs.army.mil/ProductMaps/PubForm/Details.aspx?PUB_ID=1007300

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NFPA 99, *Health Care Facilities Code*

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NFPA 54, *National Fuel Gas Code*

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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

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APPENDIX C GLOSSARY

C-1 ACRONYMS AND ABBREVIATIONS.

°C	degrees Celsius
°F	degrees Fahrenheit
AC	alternating current
AFCEC/CO	Air Force Civil Engineer Center, Operations Directorate
AFCEC/COM	Air Force Civil Engineer Center, CEMIRT
AFCEC/COO	Air Force Civil Engineer Center, Operations Maintenance
AFCEC/COSM	Air Force Civil Engineer Center, Mechanical Engineering
AFCEC/CZ	Air Force Civil Engineer Center, Environmental Directorate
AFI	Air Force Instruction
AFLCMC/WNZEC	Air Force Life Cycle Management Center
AHJ	authority having jurisdiction
ANSI	American National Standards Institute
API	American Petroleum Institute
AR	Army Regulation
ASTM	American Society for Testing and Materials
ATS	automatic transfer switch
BCE	base civil engineer
CAA	Clean Air Act
CE	Civil Engineering
CEMIRT	Civil Engineer Maintenance Inspection Repair Team
CFR	Code of Federal Regulations
CWA	Clean Water Act
DC	direct current
DoD	Department of Defense

DoDI	Department of Defense Instruction
EAID	Equipment Authorization Inventory Data
EPA	Environmental Protection Agency
EPSS	emergency power supply system
FAA	Federal Aviation Administration
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
IR	infrared
km	kilometer
kPa	kilopascal
kW	kilowatt
LOTO	lockout/tagout
LPG	liquid or liquefied petroleum gas
MAJCOM	major command
MIL-PRF	performance specification
MTS	manual transfer switch
MVA	megavolt-ampere
MW	megawatt
NEC	National Electrical Code
NERC	North American Electric Reliability Corporation
NETA	National Electric Testing Association
NFPA	National Fire Protection Association
NG	natural gas
NIST	National Institute of Standards
NSWC	Naval Surface Warfare Center
O&M	operations and maintenance

OSHA	Occupational Safety and Health Administration
p-grnd	phase to ground
pH	scale to specify how acidic or basic a water-based solution is
PM	preventive maintenance
PMTL	Preventive Maintenance Task List
p-p	phase to phase
PPE	personal protective equipment
ppm	parts per million
psi	pounds per square inch
PTO	power take off
RPIE	real property installed equipment
SAE	Society of Automotive Engineers
SCA	supplemental coolant additive
SCADA	supervisory control and data acquisition
SME	Subject Matter Expert
T.O.	Air Force Technical Order
TB	Army Technical Bulletin
UFC	Unified Facilities Criteria
UPS	uninterruptible power supply
UTC	Unit Type Code

C-2 DEFINITIONS OF TERMS.

Generator Assembly: Assembly of prime mover, electrical machinery, and all ancillary equipment. In this UFC context, it is shortened to “generator.”

Power Plant: A building or group of buildings necessary for the generation of power, including generators.

Prime Mover: Combustion engine that provides the mechanical energy in alternating electrical power. Synchronous AC machines are alternators. DC machines are generators, but not covered by the scope of this UFC.

Take: Includes to pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb wildlife. This is based upon 16 USC 1531, 16 USC 668, and 50 CFR 223.