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# **An Introduction to Operation and Maintenance of Auxiliary Power Systems**

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*This course was adapted from the Unified Facilities Criteria of the United States government, which is in the public domain.*

## **CONTENTS**

- 1. OPERATING PROCEDURES**
- 2. ROUTINE MAINTENANCE**
- 3. GENERATORS AND EXCITERS**
- 4. SWITCHGEAR MAINTENANCE**
- 5. LUBRICATING OIL PURIFICATION**

## **1. OPERATING PROCEDURES**

**1.1 REQUIREMENTS.** A successfully operating auxiliary power generating system has several requirements. First, the equipment in the system must be selected with ease of operation and maintenance as prime considerations. Second, the equipment must be installed by competent personnel.

**1.1.1 ADEQUATE RECORDS** must be kept during installation and operational shakedown so that any future modifications can be implemented with minimal research. Third, the operating personnel must be thoroughly trained in proper operating procedures. Training must include performance of maintenance as well as operation. Fourth, a detailed record keeping system must be instituted.

**1.1.2 THE RECORD KEEPING** system must include a library of the various equipment manufacturers' instructions, operating log sheets, routine maintenance instructions, maintenance log sheets, and piping and electrical drawings. The records should be assembled in binders or folders and stored in the installation's engineering office for availability and safekeeping.

## **1.2 ATTENDED STATIONS.**

**1.2.1 ATTENDED STATIONS HAVE** one or more operators on duty around the clock or for a portion of the day if the plant is not used full time. Plants that have an operator on duty only for a portion of the day sometimes require an operator's presence during the entire period that the plant is supplying power to the system. Attended stations can be operated in a manual mode, a semi-automatic mode, or an automatic mode. If the plant is manned at all times, the manual or semi-automatic mode is usually employed. In the manual mode, the operator has complete control of the power plant and would start the prime mover, bring it to operating speed, apply excitation to the generator, and close the circuit breaker to pick up the station load. When paralleling with another generator, the operator must perform the paralleling procedures described. If paralleling with the electric

utility system is desired, approval must be obtained from the utility and the need for special relaying, such as reverse power relays, must be determined.

**1.2.2 IN THE SEMI-AUTOMATIC MODE**, sensing devices monitor the normal source of power. Upon a loss of the normal power source, the sensing devices are activated which initiate a starting signal to the prime mover. An alarm circuit is also initiated at this time to alert the operator that normal power has been lost and the emergency unit has started. As the prime mover approaches rated speed, excitation is automatically applied to the generator. The power plant will then remain in this condition, i.e., rated speed and voltage, until the operator closes the circuit breaker connecting the emergency generator to the load. If the station has more than one generator, and the load requires more than one generator, the operator must initiate the synchronizing circuitry. Using the techniques provided, the operator must parallel the second generator with the first. If additional generators are required, they must be added to the system in the same manner. The operator can then adjust the governors and excitation controls to obtain the desired load division and reactive power division between generators.

**1.2.3 THE AUTOMATIC MODE** is similar to the semiautomatic mode up to the point that the unit reaches rated speed and voltage. When the speed and voltage have stabilized, if the unit is picking up a completely dead plant, a closing signal is initiated to the circuit breaker. The circuit breaker energizes the desired loads. If the load demands more than one unit, as the second unit reaches its operating speed and voltage, automatic synchronizing circuitry is enabled. The speed of the incoming unit will be adjusted automatically, and when the synchronizing relay is satisfied that the conditions are correct, a closing signal to the circuit breaker for the second unit will be sent. If additional units are needed, the automatic synchronizing circuitry will be switched as the units become available. Once normal power is again available, the procedure for returning the load to the normal bus is usually done in the manual mode. Installations that permit paralleling with the electric utility system can retransfer without an interruption of power. If paralleling is not permitted, there will be a momentary outage when the switching is performed. Some installations are designed with an automatic retransfer to normal power.

However, these are usually the smaller-rated units that use a transfer switch arrangement rather than circuit breakers for switching loads.

**1.3 UNATTENDED STATIONS.** Unattended stations operate without an operator in attendance. Their operation is the same as an attended station used in the automatic mode.

#### **1.4 NONPARALLELED STATIONS.**

**1.4.1 NONPARALLELED STATIONS** are those stations that do not have provisions for connecting the emergency generator bus to the commercial bus. It also applies to a station that has a tie breaker between two incoming lines that, because of electric utility regulations, cannot be connected together. Electrical interlocks are used to prevent an unwanted paralleling from occurring. These interlocks usually consist of two circuit breakers electrically connected. The arrangement is such that only one circuit breaker can be in the closed position at a time, thus preventing paralleling.

**1.4.2 IN SOME ARRANGEMENTS,** mechanical interlocks may also be provided. A mechanical interlock is a device that physically prevents both circuit breakers from being closed at the same time. This method also prevents paralleling from occurring.

**1.4.3 IMMEDIATELY BEFORE STARTING** the prime movers, make a thorough inspection to ensure that the following is in order. Verify that the engine generator is not set to operate in a semi-automatic or automatic starting mode during prime mover inspections. If not, extreme caution should be used. Unexpected start of prime mover while inspecting can lead to severe injury or death. Check for leaks in the lubricating system, the fuel system, and the cooling system. If any of the auxiliaries are belt-driven, check for tightness of the belts. Check for proper levels of oil, water and fuel. Look for tools or other loose objects, such as rags, that may have been left in the area, and remove. If air pressure is a part of the starting system, make sure the air pressure is at

the correct value. Verify that none of the intake air vents or exhaust ports are blocked. Start auxiliary pumps (lube oil, fuel or water) that are necessary prior to running the unit.

**1.4.4 WHEN THE PREPARATIONS** for starting have been completed, a start signal is given to the prime mover. The engine (prime mover) should start to rotate and, under control of the governor, accelerate to idling speed. Once the speed has stabilized, read the pressure and temperature gauges to make sure that normal pressure and temperatures are being maintained. Listen to any unusual noises. Shut the engine down if any unusual pressures or temperatures are observed, or if unusual noises are heard. Be familiar with the engine manufacturer's literature for information on acceptable pressures and temperatures. Once the unit has been placed under load, readings should be taken according to the operating log developed for that station. When the unit is no longer required and the load has been removed, operate the engine at no load, or at some preset idle speed to allow the engine to cool gradually. When the cooling period has expired, shut the engine down. Cooling periods vary for different prime movers. Refer to manufacturer's instructions. Stop the auxiliaries that do not stop automatically. Make an inspection of the unit, looking for any unusual conditions.

**1.4.5 IT IS ESSENTIAL** that each power generator have a complete set of standard operating procedures. The procedures include an up-to-date one-line diagram of the electrical system showing the generators and the associated switchgear components. Notes and legends are usually included with the diagram as indicated in Table 1 below.

<i>AM – Ammeter</i>	<i>AS – Ammeter Switch</i>
<i>VA4 – Voltmeter</i>	<i>VS – Voltmeter Switch</i>
<i>WM – Wutt-hour Meter</i>	<i>WHDM – Wutt-hour Demand Meter</i>
<i>CPT – Control Power Transformer</i>	<i>VAR – Volt Ampere Meter</i>
<i>CT – Current Transformer</i>	<i>PT – Potential Transformer</i>
<i>G1, G2 – Transformer</i>	<i>FU – Fuse</i>

**Table 1** – Typical notes and legends for electrical diagrams

**1.4.6 BEFORE THE UNIT** is started an inspection should be made. This can be done in conjunction with the inspection of the prime mover. Look for any material or loose parts that could be drawn into the generator. Make sure that the air flow will not be restricted either on the intake or exhaust.

**1.4.7 WHEN THE PRIME MOVER** has the generator at operating speed, excitation can be applied. Adjust the voltage regulator until the generator is at rated voltage. Adjust the governor control for the prime mover so that the generator is at rated frequency. Close the main circuit breaker connecting the generator to the load. If necessary adjust the voltage control for rated voltage and the governor control for rated frequency. Readings of various parameters are taken according to the operating log for that station. Care must be taken so that the generator is operated at or below its nameplate rating. After the unit has been shut down, a visual inspection similar to that performed prior to startup can be performed.

**1.4.8 PROPER OPERATION** of the switchgear requires a knowledge of the standard operating procedures and the familiarity with the one-line diagram of the electrical system. It requires some knowledge of the various protective relays and other devices associated with the system. The operator must be able to recognize an impending problem by observing the meters or other indicators. The operator can then take proper action. The operator must be able to perform some basic troubleshooting and maintenance.

## **1.5. PARALLELED WITH THE ELECTRIC UTILITY SYSTEM.**

**1.5.1 STATIONS THAT** can be paralleled with electric utility systems have the same basic characteristics as those discussed. They have additional features including synchronizing circuitry and, in the case of the unattended station, an automatic mode.

**1.5.2 THE PRIME MOVERS** in these stations can be operated in the manual or automatic mode. Operation in the manual mode is discussed. In the automatic mode, relays in the switchgear will sense the loss of commercial power and provide a starting signal to the



prime mover. It will then accelerate under control of the governor to the operating speed. The remainder of the prime mover operation is as previously discussed.

**1.5.3 THIS DISCUSSION** is the same as that discussed with the exception that if the station is in automatic, excitation will be applied by the automatic circuitry. Also, in automatic the main circuit breaker will close automatically, provided the incoming line circuit breaker is open.

**1.5.4 THE COMMENTS** regarding proper switchgear operation pertain to paralleling with the utility system. In addition, this type of system requires paralleling circuitry which is part of the switchgear. It includes one or more synchronizing switches, a synchroscope, synchronizing lights, incoming voltmeter, incoming frequency meter, running voltmeter, and a running frequency meter. The synchronizing circuitry is energized by turning the synchronizing switch on.

**1.5.5 THE SYNCHROSCOPE** indicates the condition of the incoming machine with respect to the bus. If the frequency of the incoming machine is higher than that of the bus, the synchroscope pointer will revolve in a clockwise or “fast” direction. The operator should adjust the governor control of the incoming prime mover until the synchroscope pointer is revolving slowly in the “fast” direction. The machines should be paralleled by closing the breaker of the incoming generator when the pointer reaches 12 o’clock. Because there is a slight lag in the breaker or switching mechanism, it is good practice to start the breaker closing operation at about the 11:30 position or slightly before the pointer reaches 12 o’clock.

**1.5.6 SYNCHRONIZING LAMPS** provide a means of checking the synchroscope for proper operation. As the pointer revolves, the lamps go alternately bright and dark in unison. Both lamps must be dark as the pointer passes 12 o’clock or the synchroscope is defective.

**1.5.7 NOW THAT THE GENERATOR** is paralleled with the electric utility system, the load (kW) can be controlled by adjusting the governor control. The reactive load (vars) can be controlled by adjusting the voltage control. To remove load from the generator, reduce the load by decreasing the governor control while observing the kW meter for the generator. When the kW meter indicates zero, open the generator circuit breaker. The load will now be transferred to the electric utility bus. The prime mover can then be shut down by following normal procedures.

## **1.6 PARALLELED WITH OTHER GENERATING UNITS.**

**1.6.1 STATIONS THAT HAVE** two or more generators that can be operated in parallel have the same basic characteristics as previously discussed. In addition, they may have automatic synchronizing circuitry and also droop circuits for the voltage regulators. The automatic synchronizing circuitry includes speed-matching relays, voltage-matching relays, and automatic synchronizing relays. These relays function when the station is in the automatic mode and when two or more AC sources are in agreement within specified limits of phase angle and frequency. The voltage regulator droop circuits are energized when two or more generators are operated in parallel. Their purpose is to prevent the undesirable condition of circulating currents between generators.

**1.6.2 PARALLEL OPERATION** of generators with regulators is accomplished by appropriate cross-current compensation. The method employs an equalizing reactor or compensator which adds a small voltage, proportional to the reactive current delivered by the generator, to the voltage delivered by the potential transformers. This gives a slight droop to the voltage held by the regulator on reactive loads and divides reactive currents in proportion to load currents. Differential compensation is used when line droop compensators are installed to automatically increase the voltage as the load increases. With this connection, all the equalizing reactors or compensators are connected in series. There is no current flow in the equalizing reactors under balanced load conditions. If the load is unbalanced, the currents flow through the regulators to decrease the excitation of

the generator carrying excessive reactive currents. This increases the excitation of the generator carrying low reactive current.

## **1.7 OPERATIONAL TESTING.**

**1.7.1 EMERGENCY GENERATOR** power units must be operated under load conditions periodically to insure their reliability. The period for this exercising will vary from station to station. It is important that accurate logs be kept of the conditions encountered during the exercising.

**1.7.2 IT IS SUGGESTED** that the manufacturer of the auxiliary power unit be consulted to determine the time intervals in which the auxiliary power unit should be exercised and the length of each exercise. National and local codes may enter into this consideration.

**1.7.3 THE PROCEDURES** used for exercising the units will also vary from station to station. The most desirable condition is to use the actual load. However, this is not always possible and in these cases a load bank can be used. A load bank is generally a portable set of resistors that allows a generator to be tested under load by disconnecting the generator from the actual load and connecting it to the load bank. In those stations that permit paralleling with the electric utility system, another method is used. After paralleling, the load on the generator can be controlled by adjusting the governor control.

**1.7.4 IN ADDITION TO EXERCISING** the units, it is also desirable to periodically perform an operational test. This test is accomplished by opening the circuit breaker from the electric utility and verifying that the necessary relays and contactors energize such that the emergency generator breaker closes and starts the auxiliary power generating system. Performance of the test simulates a loss of commercial power. The frequency of this test is dependent on the nature of the load, i.e., critical or non-critical, but is usually performed on a monthly basis.

## **2. ROUTINE MAINTENANCE**

### **2.1. INSTRUCTIONS.**

**2.1.1 MANUFACTURERS PROVIDE** specific instructions for the use and care of each of their products. Their instructions are the result of wide experience obtained under varying conditions and should be followed closely. Maintenance personnel should always check equipment first for signs of physical damage before performing any other checks.

**2.1.2 ROUTINE MAINTENANCE** instructions consist of scheduled inspections of prime movers, generators and exciters, and switchgear. When a need for service or repair is indicated, refer to the manufacturer's literature for specific information. Service records of the auxiliary power systems are filed in the installation's engineering office.

**2.1.3 MAINTENANCE INFORMATION** provided in this discussion supplements the manufacturer's instructions but does not supersede them. Checklists and schedules furnished herein are intended as guides for operators and service personnel.

**2.1.4 SINCE AUXILIARY** power systems are operated intermittently, the usual time frames for routine maintenance such as weekly, monthly, quarterly, annually may not apply. Accordingly, "short-term" is used for tasks to be performed less frequently. Exceptions are noted in the manufacturer's manual.

**2.1.5 ELECTRICAL SYSTEMS** acceptance tests are functional tests to verify the proper interaction on all sensing, processing, and action electrical devices. It is critical that these tests be performed on standby generator power systems to ascertain the safe and operational reliability of a system. A system must be tested as a united series of devices in addition to the testing of individual components. For systems that include auto-start, auto-transfer, and/or autosynchronizing equipment, every six months utility electrical power should be removed (open main circuit breaker) from a building, or part of the facility

that is supplied electrical power by commercial power/generation combination, to ascertain that the system will operate under abnormal conditions.

**2.2 PRIME MOVER MAINTENANCE.** Routine maintenance instructions for prime movers consist of short- and long-term checklists for diesel and gas turbine engines.

**2.2.1 SHORT-TERM (DIESELS).** Short-term checklist for diesel engines.

**2.2.1.1 GENERAL COMMENTS.** Before performing any tasks required by the following checklist, review the station log sheets, related records, and the manufacturer's recommendations.

**2.2.1.2 CHECKLIST.**

**2.2.1.2.1 VALUES.** Check valve operation.

**2.2.1.2.2 FUEL INJECTION NOZZLES.** Check fuel injection nozzles for secure mounting and connections each time the engine is shut down. Torque down the nozzles according to the manufacturer's instructions.

**2.2.1.2.3 STARTING SYSTEM.** Check the general condition of the air compressor, air lines, and valves, when applicable. Briefly pop open the system's safety valve weekly. Check for proper operation. Refer to manufacturer's instructions for details.

**2.2.1.2.4 GOVERNOR ALARMS AND INSTRUMENTS.** Check operation of governor alarms and instruments. Refer to manufacturer's instructions'

**2.2.1.2.5 PRESSURE GAUGES.** Check pressure gauges and clean exposed indicating elements. Refer to manufacturer's instructions.

**2.2.1.2.6 INTAKE AND EXHAUST SYSTEMS.** Check air filters and engine exhaust. A smoking exhaust indicates incorrect adjustments. Clean air filters as necessary.

**2.2.1.2.7 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.

**2.2.1.2.8 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 the fan while cleaning the coil. Check belts for condition and proper tension. Refer to manufacturer's instructions.

**2.2.1.2.9 FUEL OIL SYSTEM.** Clean fuel oil strainers as required by operating conditions. Check the system components for clean condition. Refer to manufacturer's recommendations.

**2.2.1.2.10 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.

**2.2.1.2.11 LUBRICATING SYSTEMS.** Check mechanical lubrication hourly during operation. Oil all hand lubrication points, following manufacturer's instructions. Correct leaks.

**2.2.1.2.12 SIGHT-FEED LUBRICATORS.** Clean sight-feed lubricating oil strainers as necessary. Check for adequate lubricant supply.

**2.2.1.2.13 LUBRICATING OIL FILTERS.** Check lubricating oil filters. Clean and replace filter elements as necessary.

**2.2.1.2.14 PISTON ASSEMBLY AND CONNECTING RODS.** On two-cycle engines, remove upper hand-hole inspection cover from side of engine immediately after the engine is shut down, and inspect the piston for proper lubrication.

**2.2.1.2.15 CYLINDERS AND CYLINDER HEADS.** Use compressed air to blow out indicator connections. Clean indicators and install. Refer to manufacturer's instructions.

**2.2.1.2.16 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.

**2.2.1.2.17 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.

**2.2.1.2.18 TURBOCHARGER.** Observe every four hours during operation. Check for general condition and signs of vibration. Evaluate vibration if present.

**2.2.1.2.19 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.

**2.2.2 LONG- TERM (DIESELS).** Use long-term checklists for diesel engines. Performance of checklist tasks is related to frequency and extent of use of the auxiliary power plant.

**2.2.2.1 GENERAL COMMENTS.** The following tasks should be performed annually, unless otherwise noted, following performance of short-term checks.

## **2.2.2.2. CHECKLIST AND SCHEDULE.**

**2.2.2.2.1 VALVE INSPECTION.** Inspect exhaust valves; clean and remove carbon on two-cycle engines and valves as necessary. Refer to manufacturer's instructions.

**2.2.2.2.2 INLET VALVES.** . Inspect and regrind inlet and exhaust valves and valve seats as necessary. Refer to manufacturer's instructions.

**2.2.2.2.3 VALVE SPRINGS AND GUIDES.** Check valve spring length and tension and inspect valve stems, bushings, and guides annually or after 2000 hours of use, whichever comes first. Replace parts as necessary. Refer to manufacturer's instructions.

**2.2.2.2.4 CAMSHAFT AND DRIVE.** Check and adjust gears and/or timing chain. Refer to manufacturer's instructions.

**2.2.2.2.5 CAMSHAFT BEARINGS.** Inspect and adjust camshaft bearing clearances. Refer to manufacturer's instructions.

**2.2.2.2.6 FUEL INJECTION NOZZLE INSPECTION.** After 2000 hours of use, remove and check nozzles in the test stand. Service and adjust nozzles following manufacturer's instruction.

**2.2.2.2.7 FUEL INJECTION PUMPS.** Inspect fuel injection pumps for secure mounting, cleanliness, and proper operation.

**2.2.2.2.8 FUEL INJECTION PUMP INSPECTION.** Disassemble and recondition all injection pump nozzles after 2000 hours of use. Repair or replace worn or damaged parts. Reassemble and adjust, following the manufacturer's instructions.

**2.2.2.2.9 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.



**2.2.2.2.10 AIR VALVES.** Clean air valves and reseal if necessary. Refer to manufacturer's instructions.

**2.2.2.2.11 AIR COMPRESSOR.** Disassemble and overhaul the air compressor and starting equipment every five years based on frequency of use of the auxiliary power plant.

**2.2.2.2.12 PRESSURE GAUGE INSPECTION.** Check the date of calibration. Verify that gauges have valid calibration certification. Calibrate per manufacturer's instructions as required.

**2.2.2.2.13 GOVERNOR OVERHAUL.** Overhaul the governor after 2000 hours of use or when needed as indicated. Repair or replace worn or damaged parts. Reassemble and adjust, following the manufacturer's instructions.

**2.2.2.2.14 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.

**2.2.2.2.15 COOLING SYSTEMS.** Inspect piping and valves for leaks and clean the heat exchanger. Perform cooling system maintenance per manufacturer's instructions. Drain and clean cooling tower; clean and inspect piping, circulating pumps and equipment.

**2.2.2.2.17 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.

**2.2.2.2.18 FUEL OIL TANKS AND LINES.** Drain service tanks and lines. Remove water and sediment. Check heating coil for proper operation.

**2.2.2.2.19 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.

**2.2.2.2.20 CRANKCASE.** Drain crankcase semi-annually or more frequently based on the number of hours run per manufacturer's recommendations or acceptable industrial engine maintenance procedures. Inspect lubricating oil pumps; flush crankcase and refill. Refer to manufacturer's instructions.

**2.2.2.2.21 LUBRICATING OIL PUMP.** Inspect the pump after 2000 hours of use for proper operation. Refer To manufacturer's specifications for the pump.

**2.2.2.2.22 CYLINDER HEADS.** Remove cylinder heads according to the manufacturer's instructions after 2000 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.

**2.2.2.2.23 PISTON ASSEMBLY INSPECTION.** On four-cycle engines, pull one piston after 2000 hours of use and inspect for proper cooling, lubrication and carbon deposits. Inspect piston rings, wrist pin and the cylinder liner for compliance with engine manufacturer's specifications.

**2.2.2.2.24 INSPECTION OF PISTONS.** Pull pistons after 4000 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.

**2.2.2.2.25 CYLINDER INSPECTION.** Use the barring device (jacking bar) to turn each piston to top dead center. Inspect each cylinder liner for scoring. Refer to manufacturer's instructions.

**2.2.2.2.26 ANCHOR BOLTS.** Check anchor bolts for proper torque value.

**2.2.2.2.27 FLYWHEEL BOLTS.** Check flywheel bolts for proper torque value. Refer to manufacturer's instructions. Verify alignment and coupling to generator, comply with specifications.

**2.2.2.2.28 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.

**2.2.2.2.29 CRANKSHAFT.** Verify compliance with engine manufacturer's specifications. Examine crankshaft for cracks. Measure distance between crankwebs for crankshaft deflection. Check journal level and clean oil passages. Replace bearings as necessary and adjust running clearance following the manufacturer's instructions.

**2.2.2.2.30 TURBOCHARGER INSPECTION.** Disassemble, clean and inspect entire turbocharger following the manufacturer's instructions and specifications.

**2.2.2.2.31 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.

**2.2.3 SHORT-TERM (GAS TURBINES).** Use short-term checklists for gas turbines. Checks are limited to inspection and cleaning tasks that can be performed on the exterior of an engine.

**2.2.3.1 GENERAL COMMENTS.** Before performing any tasks required by the following checklist, review the station log sheets, related records and the manufacturer's recommendations.

**2.2.3.2 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.

### **2.2.3.3 CHECKLIST.**

**2.2.3.3.1 INLET INSPECTION.** Verify that the inlet drain at the lower part of duct is open and free of any obstruction so that 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.

**2.2.3.3.2 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.

**2.2.3.3.3 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.

**2.2.3.3.4 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 described previously. 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.

**2.2.4 LONG-TERM (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.

**3. GENERATORS AND EXCITERS.** Routine maintenance instructions for generators and exciters consist of short- and long-term checklists for rotating and static type equipment.

**3.1 SHORT- TERM.** Short-term checklists for generators and exciters.

**3.1.1 GENERAL COMMENTS.** Before performing any tasks required by the following checklist, review the station log sheets, related records and the manufacturer's recommendations.

### **3.1.2 CHECKLIST**

**3.1.2.1 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.

**3.1.2.2 EXCITER COUPLING (IF APPLICABLE).** When the generator unit is shut down prior to operation, wipe off excess lubrication from the coupling to prevent spatter.

**3.1.2.3 COUPLING LEAKS AND ALIGNMENT.** When the generator has been shut down, check for lubrication leaks and tightness of coupling. Note any evidence of improper alignment and correct if necessary.

**3.1.2.4 AXIAL POSITION.** Check axial position of the prime mover, generator and exciter shafts for correct alignment and angularity.

**3.1.2.5 BEARINGS.** Lubrication of generator and exciter bearings is required. Refer to manufacturer's literature for instructions for pressure and non-pressure lubricated bearings.

**3.1.2.6 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 monthly. Check brushes for wear and indications of arcing and chattering monthly. Check condition of slip rings. Refer to manufacturer's instructions.

**3.1.2.7 STATIC EXCITERS.** Verify that the equipment is clean and free from dirt and moisture. Verify that all connections are tight. Check connections for corrosion and clean as required.

**3.2 LONG-TERM.** Long-term checklists for generators and exciters.

**3.2.1 GENERAL COMMENTS.** The following tasks should be performed annually unless otherwise noted, following performance of short-term checks.

**3.2.2 CHECKLIST AND SCHEDULE.**

**3.2.2.1 COUPLING LUBRICATION.** Drain lubricant, disassemble and clean the coupling annually or whenever necessary. Reassemble, using new gaskets and fresh lubricant. Refer to manufacturer's instructions for flexible coupling.

**3.2.2.2 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 on brush riding surface. Repair and replace damaged or worn brush rigging parts. Refer to manufacturer's instructions.

**3.2.2.3 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.

**3.2.2.4 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. Check for roughness, hard spots and out-of-round condition. Service commutator and collector rings as necessary following manufacturer's instructions.

**3.2.2.5 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. 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 the field coils and the 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.

**3.2.2.6 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.

**3.2.2.7 STATOR WINDING.** Measure and record insulation resistance between the stator winding and the ground at the machine terminals annually.

**3.2.2.8 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.

**3.2.3 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.

**4. SWITCHGEAR MAINTENANCE.** Routine maintenance instructions for switchgear consist of short- and long-term checklists. Deenergize switchgear before performing maintenance. Disconnect primary and secondary sources of power.

**4.1 SHORT-TERM.** Short-term checklists for switchgear.

**4.1.1 GENERAL COMMENTS.** Before performing any tasks required by the following checklist, review the station log sheets, related records, manufacturer's recommendations and NFPA-70E, Electrical Safety Requirements for Employee Workplaces.

**4.2 CHECKLIST.**

**4.2.1 PANELS AND OTHER EXTERIOR SURFACES.** Panels and exterior surfaces must be kept rigorously clean at all times.

**4.2.2 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, overspeed, liquid level, lubricating oil pressure and/or flow, frequency change, etc. Refer to manufacturer's literature for inspection procedures. Verify that all connections are tight and free of corrosion.

**4.2.3 CONDUCTORS AND COILS.** Clean and inspect conductors and coils monthly. Verify that coating of insulating varnish is in good condition (clean, smooth and polished) and there are no indications of overheating or corona arcing.

**4.2.4 SWITCHES.** Inspect switches for proper alignment, firm contacts and smooth operation monthly. Burned or pitted copper contact surfaces may be dressed with 2/0 sandpaper. Do not dress silver contacts.

**4.2.5 CIRCUIT BREAKERS.** Trip and close circuit breakers, check for proper operation quarterly. Check time delay and freedom of movement. Refer to manufacturer's instructions.

**4.2.6 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.

**4.2.7 CONTACTORS.** Check magnet surfaces of contactors quarterly for cleanliness. Remove gun, rust or corrosion. Adjust for even contact pressure according to manufacturer's instructions.

**4.2.8 VOLTAGE REGULATORS.** Check voltage regulators for proper operation and adjustments quarterly. Various makes and types are used. Refer to the manufacturer's literature for instructions.

**4.3 LONG- TERM.** Long-term checklists for switchgear. Performance of tasks is related to frequency and extent of use of the auxiliary power plant.

**4.3.1 GENERAL COMMENTS.** The following tasks should be performed annually unless otherwise noted, following performance of short-term checks. The procedures are general but apply primarily to draw-out equipment.

#### **4.3.2 CHECKLIST AND SCHEDULE.**

**4.3.2.1 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.

**4.3.2.2 BUSES.** Inspect 'buses and connections for signs of overheating or weakening of insulating supports. Overheating is indicated by discoloration of the busbar. Inspect

insulators for cracks and/or arc tracks. Replace defective insulators. Tighten busbar and terminal connections to the proper torque value.

**4.3.2.3 INDICATING DEVICES AND INTERLOCKS.** Check indicating devices and interlocks for proper operation. Refer to manufacturer's instructions.

**4.3.2.4 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.

**4.3.2.5 ENCLOSURE.** Verify that interior anchor bolts and structural bolts are tight. Inspect cable connections for signs of overheating. Tighten loose connections as required.

**4.3.2.6 CIRCUIT BREAKERS.** Manually operate each breaker while in test position, verify proper operation. Refer to manufacturer's instructions.

**4.3.2.7 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.

**4.3.2.8 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.

## **5. LUBRICATING OIL PURIFICATION**

**5.1 PURIFICATION SYSTEMS.** Oil purification systems, either in the engine pressure system or oil supply system are classified by the method of flow used' in purifying the oil. The systems frequently used are the bypass and full-flow types as follows:

**5.1.1 IN THE BYPASS SYSTEM** part of the total oil circulating in the engine passes through the filter or purifying equipment. The system continuously cleans a small portion of the oil and, in general, removes contaminants as fast as they are formed in the engine. Thus, new oil may deteriorate but will gradually stabilize when the effectiveness of the filtration system matches the rate of production of contaminants.

**5.1.2 IN THE FULL-FLOW SYSTEM** all of the oil circulating in the engine passes through filtering equipment prior to going to the engine.

**5.2 FORMS OF CONTAMINATION.** Oil contamination usually occurs in one of two forms:

**5.2.1 IMPURITIES** such as dirt, carbon particles or other solid matter entering the oil.

**5.2.2 UNDESIRABLE SUBSTANCES** such as water, polymerized products of oil breakdown, acids and other chemical matter entering the oil.

**5.3 METHODS OF PURIFYING.** Oil purification is accomplished by the use of one, or any combination, of the following methods: straining, filtering, centrifuging or reclaiming.

**5.3.1 STRAINING.** The usual type of oil strainer can be woven wire screen or perforated sheet metal. Edge-type and wire-wound strainers are also used. The edge-type consists of stacks of metal discs separated by thin washers. The wire-wound type consists of a spool wrapped with finely serrated wire forming a clearance between adjacent wires. Strainers are designed to remove solid particles from the oil, usually between 0.0015 and 0.003 inches in size, depending on the engine manufacturer's specifications.

Refer to the strainer manufacturer's literature for details and servicing instructions.

**5.3.2 FILTERING.** Filtering is accomplished using chemically neutral or chemically activated filtering material.

**5.3.2.1 CHEMICALLY NEUTRAL.** The oil filter usually consists of a canister or tank containing a chemically neutral, highly absorbent material. Cotton, cellulose waste, or paper is usually used as the absorbent filtering material. The filter tank is provided with necessary entry and exit ports, internal tubing (perforated and solid), check valves and orifices to ensure proper flow of the oil through the filtering material. Filters are more efficient than strainers in removing very small particles and are designed to process strained oil. Refer to the filter manufacturer's literature for details servicing instructions.

**5.3.2.2 CHEMICALLY ACTIIVATED.** Absorbent filters contain chemically activated material instead of chemically neutral material. Construction of absorbent-type and adsorbent-type filters is similar. The filtering materials include charcoal, clay and fuller's earth. These materials remove water, acidic components, and may absorb certain light petroleum elements, waxes or residual products. They usually accomplish good purification and may reduce acidity as well as remove the solid contaminants. Absorbent or adsorbent filters may be used on straight run, uncompounded mineral oils where there is no danger of removing essential additives. Absorbent filters (chemically-neutral filters) should be used in conjunction with compounded or additive-type oil. Refer to the filter manufacturer's literature for details and servicing instructions. Ensure that the filtering system complies with the engine manufacturer's recommendations.

**5.3.3 CENTRIFUGING.** An oil purification centrifuge usually consists of a stationary bowl that encloses a rotating element. The element, mounted on a vertically arranged axis, rotates at a high speed within the bowl. High-speed rotation causes a column of oil to form in the portion of the element nearest the center and a column of water to balance this at the outer edge of the centrifuge bowl. Solid particles having a gravity value heavier than that of the oil are thrown outward, and the heavy solids accumulate in the centrifuge

bowl. Water is removed by the high gravity differential produced by the high speed of the centrifuge. Effective mechanical separation occurs; however, materials in a suspended state are not always removed by this method. Chemical contaminants are separated only if they have a markedly different specific gravity from that of the oil. Polymerized products having a gravity similar to that of oil are not separated and, in general, fuel oil dilution is not affected or corrected. The centrifuge is used extensively in fuel oil purification but has reduced application to diesel and internal combustion engine lubricants. If used in an oil reclaiming system, it is usually only a part of the total process. Refer to the manufacturer's literature for details and servicing instructions.

**5.3.4 RECLAIMING.** Various types of oil reclaiming equipment are used. Most reclaimers operate with the oil heated at about 400°F, which drives off water vapor and lighter fuel oil dilution. Highly effective reclamation of regular mineral oil is possible. Almost complete removal of additive material occurs during reclaiming. Oils produced from a reclaimer must be limited to services not requiring an additive oil. Operation at temperatures above 400°F results in partial breakdown of the lubricating oil, which can produce an oil having a higher viscosity than the original oil. Oil reclaimers are normally used for processing oil between the impure oil and the clean oil system or may route the reclaimed oil to a separate tank for use in other lubricating services. Refer to the manufacturer's literature for details and servicing instructions.

**5.3.5 OIL QUALITY STANDARDS.** Oil quality standards are provided in Table 2 below.

Parameter	Normal	Maximum
Water and Sediment	1.0%	5.0%
Water	0.5%	3.0%
Sediment	0.5%	2.0%
Viscosity	±5.0%	±10.0%
Corrosion (copper strip)	None	Dull
pH	7% or higher	6.8%
Filtered Particles - Larger than oil filter	None	2.0%
Filtered Particles - Metallic under 1 micron	Few	1.0%
Filtered Particles - Metallic over 5 micron	None	1.0%

**Table 2** - Oil quality standards

**5.4 OIL MAINTENANCE PROCEDURES.** The following information is a general guide for maintenance of lubricating oil.

**5.4.1 WATER AND SEDIMENT.** Clean by centrifuging.

**5.4.2 VISCOSITY.** Treat with oil reclaimer to drive off dilution.

**5.4.3 VISCOSITY.** Centrifuge (hot) to remove heavy sludge. If necessary, add straight run mineral oil of lower viscosity.

**5.4.4 CORROSION.** Treat with activated-type reclaimer. If an additive oil is in use, the presence of corrosive qualities indicates that 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.

**5.4.5 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.