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Basics of Mobile Power Plant Generators

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Chapter 6

Power Generation

Topics

1.0.0 Power Generation

2.0.0 Emergency/Standby Power

3.0.0 Generator Installation

4.0.0 Generating Plant Operations

5.0.0 Servicing Generators

6.0.0 Distribution Panelboards

7.0.0 Power Plant Maintenance

8.0.0 TQG-B Generator

To hear audio, click on the box.

Overview

Generators are very important to your assignment with the Seabees. Whether you operate them as a main power source, as standby power, or as emergency power, you need a thorough knowledge of their hookup, operation, and maintenance.

As a Construction Electrician, you may be responsible for installing, maintaining, and repairing electrical power generation equipment. In time of war or national emergency, Advanced Base Functional Components (ABFC) will normally be used at temporary overseas bases. Even in peacetime, generation equipment is used at remote bases or as emergency and backup power on most naval bases.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe power generation.
2. Describe emergency and standby power procedures.
3. Describe generator installation procedures.
4. Describe servicing procedures associated with generators.
5. Describe the operation of distribution panels.
6. Describe plant operations associated with generators.
7. Describe generator power plant maintenance procedures.
8. Describe the components and operation of the TQG-B generator.

Prerequisites

None

This course map shows all of the chapters in Construction Electrician Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Test Equipment, Motors, and Controllers	↑	C E
Communications and Lighting Systems		
Interior Wiring and Lighting		
Power Distribution		
Power Generation		
Basic Line Construction/Maintenance Vehicle Operations and Maintenance		B A
Pole Climbing and Rescue		S
Drawings and Specifications		I
Construction Support		C
Basic Electrical Theory and Mathematics		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select

anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 POWER GENERATION

The characteristics built into naval electrical installations are simplicity, ruggedness, reliability, and flexibility to permit continued service. Those who operate these plants must make full use of the installation's inherent capabilities and maintain, as far as possible, uninterrupted availability of electrical power where it is needed. To do this, operating personnel must possess the following:

- Thorough knowledge of how to operate and maintain the components of an electrical plant.
- Complete familiarity with the electrical plants distribution capabilities.
- Understanding of the electrical system operation of the base.
- The ability to apply electrical and electronic principles to specific installations.
- The sizing and installation of secondary conductors.

2.0.0 EMERGENCY/STANDBY POWER

When you set up an emergency/standby power system, you must consider numerous factors. The following will cover a few of the situations you may encounter. This chapter does not include the automatic transfer aspect of switching to backup power, since this task is performed by someone with a Navy Enlisted Classification (NEC) code, CE-5601. For our discussion in this section, we will be using the term "emergency", the concepts involved are equally applicable to "standby" systems. Remember that the National Electrical Code® requires emergency and standby systems to be kept entirely separate from all other wiring and equipment. For more detailed information, see article 700 of the National Electrical Code®.

2.1.0 System Design

Whether you are designing and installing an emergency backup system or operating and maintaining an existing system, you must be completely familiar with the installation requirements and physical characteristics of the equipment. The design, material, and installation must comply with electrical safety standards and codes.

In general, emergency power replaces "normal" power. The choice of arrangement and the size and the type of equipment depend in large measure on the loads to be fed from the emergency system. The system includes all devices, wiring, raceways, transfer switch, energy source, and other electrical equipment required to supply power to selected loads. These selected loads will be determined by the available power from your emergency power source. *Figures 6-1* and *6-2* show two possible arrangements for emergency/standby power hookups.

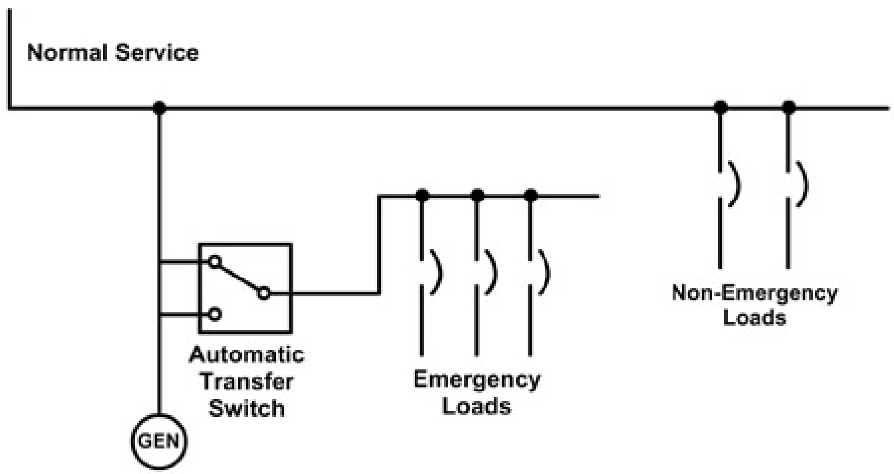

Figure 6-1 – Single transfer switch.

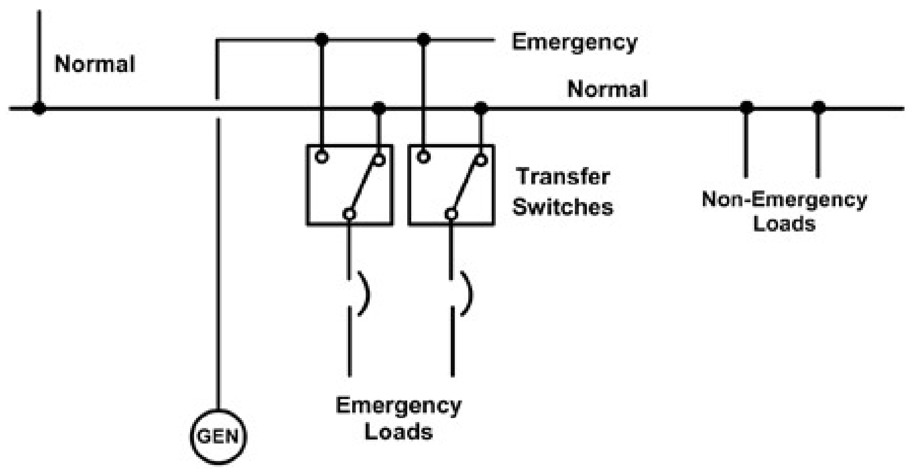

Figure 6-2 – Multiple transfer switches.

3.0.0 GENERATOR INSTALLATION

Several factors should be considered before a final decision is made about where to locate a generator. The noise levels of generators sized from 5 kW to 200 kW range from 77 dBa to 93 dBa (adjusted decibels) at 25 feet. Generator noise is a problem in low-noise level or quiet areas (libraries, offices, hospitals, chapels, etc.). The operating 60-kW generator, for example, presents a noise hazard (84 dBa to 91 dBa, depending on the model) to all personnel in the immediate area. The noise level near the unit exceeds the allowable limits for unprotected personnel. Therefore, everyone working around the generator needs single (noise < 84 dBa) or double hearing protection (noise > 104 dBa).

Placing a generator set near points of large demand will reduce the size of wire required, hold the line losses to a minimum, and afford adequate voltage control at the remote ends of the lines.

The following points should be considered before an exact site is chosen for a generator set:

1. Generators must not be closer than 25 feet (7.6 meters) to a load because of noise, fire hazard, and air circulation.
2. The set must be placed on a stable, preferably level, foundation. It should not be operated while inclined more than 15 degrees from level.

3. The site must be within 25 feet (7.6 meters) of any paralleled generator set and within 25 feet (7.6 meters) of any auxiliary fuel supply.
4. When preparing a temporary installation, you should move the generator set as close to the jobsite as practical. In an area where the ground is soft, do not remove the wood-skid base if you have not already done so. The wood-skid base will establish a firm foundation on soft ground, mud, or snow; otherwise, use planks, logs, or other material for a base in an area where the ground is soft.

The generator can be moved by lifting or pulling. The generator set comes equipped with a lifting sling, usually stored in the skid on the side of the unit opposite the operator's control panel.

3.1.0 Generator Selection

When a base is first established and electrical power is required in a hurry, you will not have time to set up a centrally located generating station; instead, you will spot a portable plant at each important location requiring power. *Table 6-1* lists some of the standard alternating current (AC) generators available. These standard generators are capable of meeting the power requirements of advanced bases and those for permanent or portable emergency power.

Table 6-1 – Types of portable generators.

	Alternating Current					
Frequency			**60 hertz**			
Voltage	120		120/208		120/208 240/416	
Phase	1		1 & 3		3	
Wires	2		4*		4	
Fuel	G	D	G	D	G	D
kW Rating						
5	X		X	X		X
10			X	X		
15			X	X		
30				X		X
60				X		X
100				X		X
200						X
G – Gasoline driven. **D** – Diesel driven. ***** - Panel connections permit, at rated kW output: 120/208V 3 phase 4 wire, 120V 3 phase 3 wire, 120V single phase 2 wire, 120/240V single phase 3 wire						

The electrical loads to be supplied power, voltage, phase, frequency, and duty cycle requirements govern the selection of generating equipment. Probable load deviation, probable life of the installation, availability of fuels, and availability of skilled personnel are other important factors.

Electrical plants serve a varied load of lighting, heating, and power equipment, most of which demand power day and night. The annual load factor (the ratio of average power to peak power) of a well-operated active base should be 50 percent or more with a power factor of 80 percent or higher. If the load is more than a few hundred feet from the power source, a high-voltage distribution system may be required.

If several generators are to serve primary distribution systems, they should generate the same voltage to avoid the need for voltage transformation. The number of phases required by the load may differ from that produced by the generator. As loads usually can be divided and balanced between phases, most generators of appreciable size are wound for three phase operation.

3.1.1 Power and Voltage Requirements

The selection of voltage is affected by the size, character, and distribution of the load; length, capacity, and type of transmission and distribution circuits; and size, location, and connection of generators. Practically all general-purpose lighting in the United States and at United States overseas bases is 120 volts. The lighting voltage may be obtained from a three-wire, 120/240-volt, single-phase circuit or a 120/208-volt, three-phase, four-wire circuit.

Small motors can be supplied by single-phase AC at normally 120 volts. Large three-phase, AC motors above 5 horsepower (hp) generally operate satisfactorily at any voltage between 200 and 240. The use of combined light and power circuits will be accomplished by the use of 240- or 208-volt systems.

3.1.2 Computation of the Load

As mentioned earlier, you must take various factors into consideration in selecting the required generating equipment. The following technical data will help you compute the load.

Before designing any part of the system, you must determine the amount of power to be transmitted, or the electrical load. Electrical loads are generally measured in terms of amperes, kilowatts, or kilovoltamperes. In general, electrical loads are seldom constant for any appreciable time, but fluctuate constantly. To calculate the electrical load, determine the connected load first. The connected load is the sum of the rated capacities of all electrical appliances, lamps, motors, and so on, connected to the wiring of the system. The maximum demand load is the greatest value of all connected loads that are in operation over a specified period of time. Knowledge of the maximum demand of groups of loads is of great importance because the group maximum demand determines the size of generators, conductors, and apparatuses throughout the electrical system.

The ratio between the actual maximum demand and the connected load is called the ***DEMAND FACTOR***. If a group of loads were all connected to the supply source and drew their rated loads at the same time, the demand factor would be 1.00. There are two main reasons why the demand factor is usually less than 1.00. First, all load devices are seldom in use at the same time and, even if they are, they will seldom reach maximum demand at the same time. Second, some load devices are usually slightly larger than the minimum size needed and normally draw less than their rated load. Since maximum demand is one of the factors determining the size of conductors, it is important to establish the demand factor as closely as possible.

The demand factor varies considerably for different types of loads, services, and structures. The National Electrical Code®. Article 220 provides the requirements for determining demand factors. Demand factors for some military structures are given in *Table 6-2*.

Table 6-2 – Demand factor.

Structure	Demand Factor
Housing	0.9
Aircraft Maintenance Facilities	0.7
Operation Facilities	0.8
Administrative Facilities	0.8
Shops	0.7
Warehouses	0.5
Medical Facilities	0.8
Theaters	3.0
NAV Aids	0.5
Laundry, Ice Plants, and Bakeries	1.0
All others	0.9

Example: A machine shop has a total connected load of 50.3 kilowatts. The demand factor for this type of structure is taken at 0.70. The maximum demand is 50.3 × 0.70 = 35.21 kilowatts.

3.2.0 Site Selection

Before selecting a site, study a plot or chart of the area on which the individual buildings and facilities have been plotted (See *Figure 6-3*). Select a site large enough to meet present and anticipated needs. Then select a location with sufficient space on all sides for servicing and operating the unit. It should be level, dry, and well drained. If this type of site is not available, place the generator set on planks or logs for a suitable base foundation.

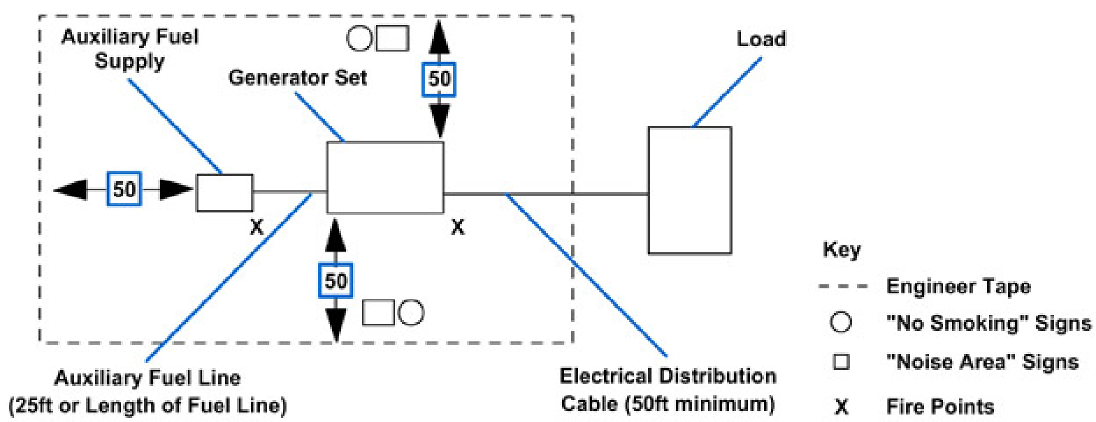

Figure 6-3 – Generator site selection.

3.3.0 Sheltering the Generator

Although advanced base portable generators are designed to be operated outdoors, prolonged exposure to wind. rain. and other adverse conditions will definitely shorten their lives. If the generators are to remain on the site for an extended period of time, mount them on solid-concrete foundations and install them under some type of shelter. See *Figure 6-4*.

Figure 6-4 – Generator shelter.

Presently, there are no predrawn plans for shelters for a small advanced base generating station. The shelter will be an on-the-spot affair, the construction of which is determined by the equipment and material on hand plus your ingenuity and common sense.

Before a Builder (BU) can get started on the shelter, you will have to inform him or her of such things as the number of generators to be sheltered, the dimensions of the generators, the method of running the generator load cables from the generator to the distribution system outside the building; and the arrangement of the exhaust system, radiator discharge, and cooling air. Installation specifications are available in the manufacturer's instruction manual that accompanies each unit. Be sure to use them. Appropriate consultation with the BU regarding these specifications may help minimize various installation and piping problems and costs.

The following hints and suggestions also will be helpful:

- Ventilation is an important factor to consider when installing the units inside a building. Every internal combustion engine is a HEAT engine. Although heat does the work, excess amounts of heat must be removed if the engine is to function properly. Heat can be removed by setting the engine radiator grille near an opening in the wall and providing another opening directly opposite the unit. In this manner, cool air can be drawn in and the hot air directed outdoors. These openings can be shielded with adjustable louvers to prevent the entrance of rain, sand, or snow. In addition, when the engine is operating in extremely cold weather. the temperature in the room can be controlled by simply closing a portion of the discharge opening. Additional doors or windows should be provided in the shelter if the plants are installed in localities where the summer temperatures exceed 80°F at any time.
- Working space is another consideration. Be sure to provide sufficient space around each unit for repairs or disassembly and for easy access to the generator control panels.

- The carbon monoxide gas present in the exhaust of the engine is extremely poisonous. Under no circumstances should this gas be allowed to collect in a closed room; (Refer to *Figure 6-5*) therefore, you must provide means to discharge the engine exhaust to the outdoors. Exhaust can be vented by extending the exhaust pipe through the wall or roof of the building. Support the exhaust pipe, make certain that there is no obstruction, and avoid right-angle bends, if possible. Also, whenever possible, arrange the exhaust system so that the piping slopes away from the engine. In this way, condensation will not drain back into the cylinders. If the exhaust pipe should have to be installed so that loops or traps are necessary, place a drain cock at the lowest point of the system. All joints have to be perfectly tight, and where the exhaust pipe passes through the wall, you have to prevent the discharged gas from returning along the outside of the pipe back into the building. Exhaust piping inside the building has to be covered with insulation capable of withstanding a temperature of 1500°F.

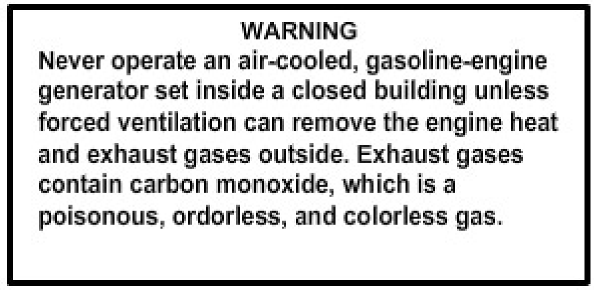

Figure 6-5 – Exhaust gas warning label.

After the generating units have been set in place and bolted down, BUs can proceed to erect the building, using the necessary information provided by the Construction Electricians (CE).

3.4.0 Generator Set Inspection

After setting up a portable generator, your crew must do some preliminary work before placing it in operation. First, they should make an overall visual inspection of the generator. Have them look for broken or loose electrical connections, bolts, and cap screws, and see that the ground terminal wire (No. 6 American Wire Gauge (AWG) minimum) is properly connected to the ground rod/grounding system. Check the technical manual furnished with the generator for wiring diagrams, voltage outputs, feeder connections, and prestart preparation. If you find any faults, correct them immediately.

3.4.1 Generator Connections

When you install a power plant that has a dual voltage alternator unit, make certain that the stator coil leads are properly connected to produce the voltage required by the equipment.

Proper grounding is also a necessity for personnel safety and for prevention of unstable, fluctuating generator output.

3.4.1.1 Internal Leads

The voltage changeover board (See *Figure 6-6*) permits reconnection of the generator phase windings to give all specified output voltages. One end of each coil of each phase winding runs from the generator through an instrumentation package and a static exciter current transformer to the reconnection panel. This routing assures current sensing in each phase regardless of voltage connection at the reconnection board assembly. The changeover board assembly is equipped with a voltage change board to facilitate conversion to 120/208 or 240/416 generator output voltage. Positioning of the voltage change board connects two coils of each phase in series or in parallel. In parallel, the output is 120/208; in series, the output is 240/416 volts ac. The terminals on the changeover board assembly for connection to the generator loads are numbered according to the particular coil end of each phase of the generator to ensure proper connections.

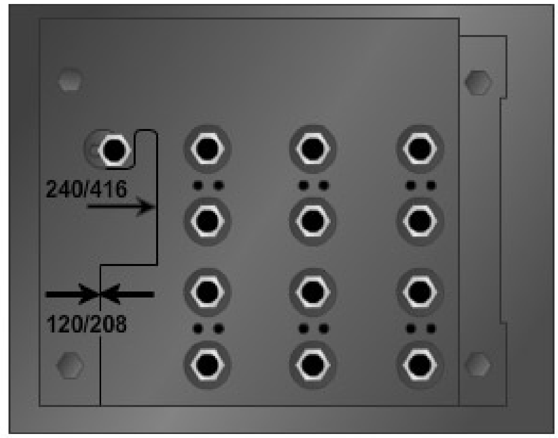

Figure 6-6 – Typical changeover board assembly.

Remember that you are responsible for the proper operation of the generating unit; therefore, proceed with caution on any reconnection job. Study the wiring diagrams of the plant and follow the manufacturer's instructions to the letter. Before starting the plant up and closing the circuit breaker, double-check all connections.

3.5.0 Grounding

The generator set must be connected to a suitable ground before operation. (*Figure 6-7*)

WARNING

Electrical faults in the generator set, load lines, or load equipment can cause injury or electrocution from contact with an ungrounded generator.

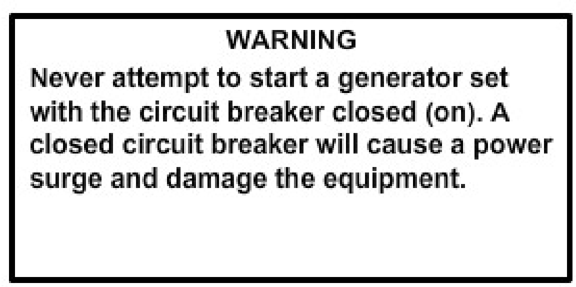

Figure 6-7 – Generator start up warning label.

3.5.1 Grounding Procedures

The ground can be, in order of preference, an underground metallic water piping system (*Figure 6-8*, view A), a driven metal rod (*Figure 6-8*, view B), or a buried metal plate (*Figure 6-8*, view C). A ground rod must have a minimum diameter of 5/8 inches if solid or 3/4 inches if pipe. The rod must be driven to a minimum depth of 8 feet . A ground plate must have a minimum area of 2 square feet and, where practical, be embedded below the permanent moisture level.

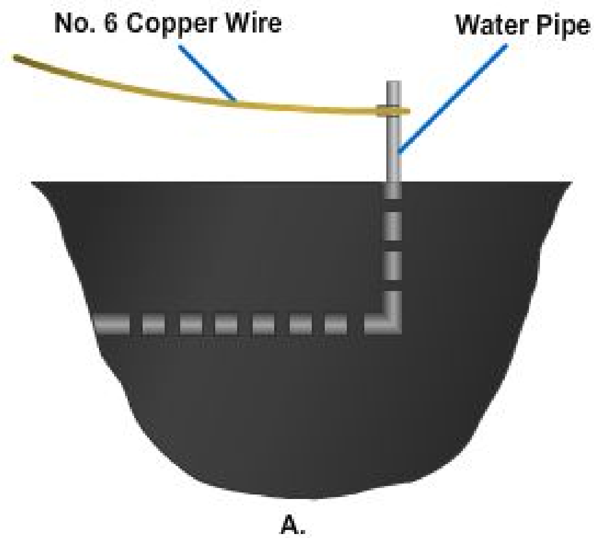

Figure 6-8 – Methods of grounding generators.

The ground lead must be at least No. 6 AWG copper wire. Be sure to bolt or clamp the lead to the rod, plate, or piping system. Connect the other end of the ground lead to the generator set ground terminal stud (*Figure 6-9*, view A).

Use the following procedure to install ground rods:

- Install the ground cable into the slot in the ground stud and tighten the nut against the cable.
- Connect a ground rod coupling to the rod and install the driving stud in the coupling (*Figure 6-9*, View B). Make sure that the driving stud is bottomed on the ground rod.
- Drive the ground rod into the ground until the ***coupling*** is just above the ground surface.
- Connect additional rod sections, as required, by removing the driving stud from the coupling. Make sure the new ground rod section is bottomed on the ground rod section previously installed. Connect another coupling on the new section and again install the driving stud.
- After the rod(s) have been driven into the ground, remove the driving stud and the top coupling.

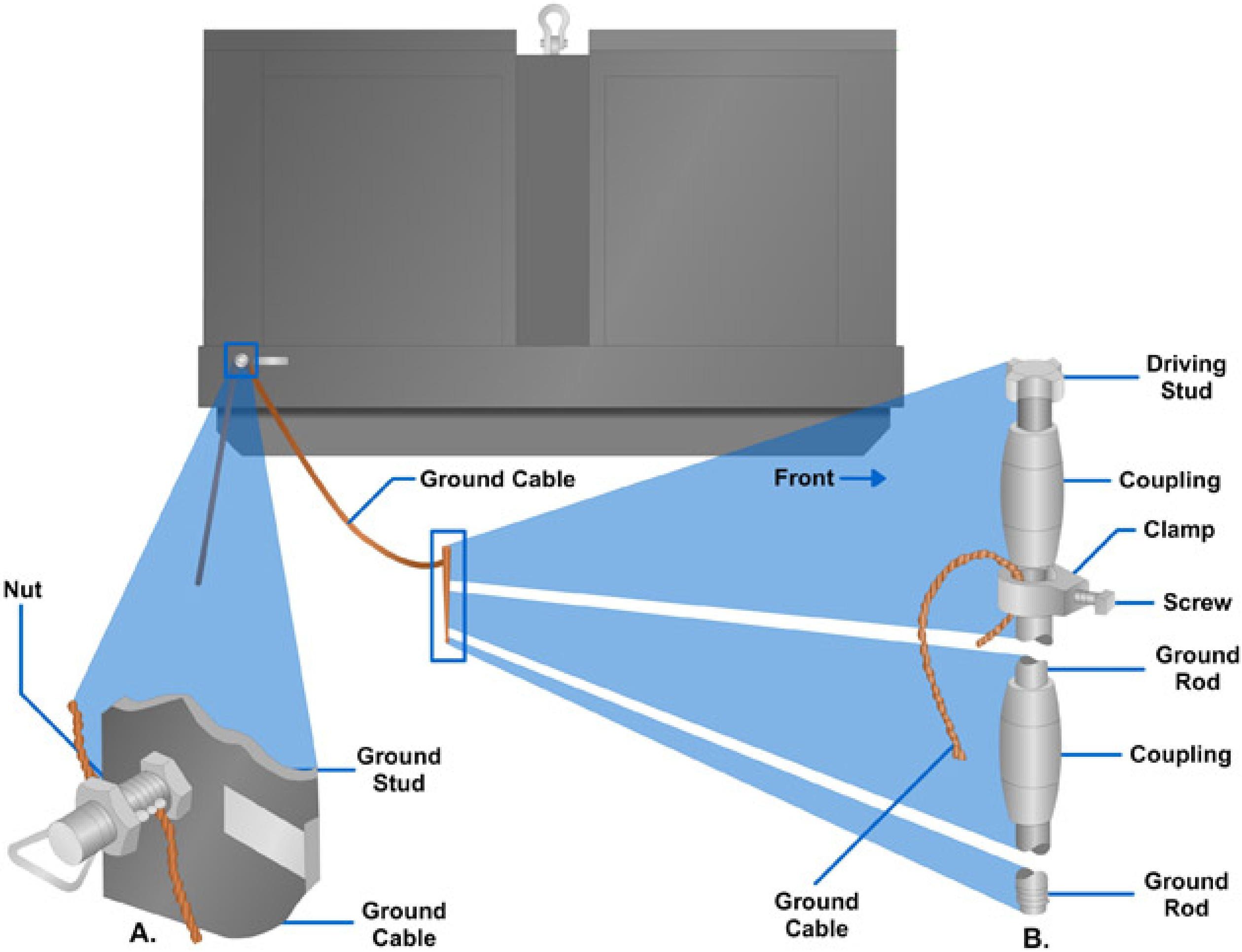

Figure 6-9 – Grounding procedure.

NOTE

The National Electrical Code© states that a single electrode consisting of a rod, pipe, or plate that does not have a resistance to ground of 25 ohms or less will be augmented by additional electrodes. Where multiple rod, pipe, or plate electrodes are installed to meet the requirements, they will be not less than 6 feet apart.

The resistance of a ground electrode is determined primarily by the earth surrounding the electrode. The diameter of the rod has only a negligible effect on the resistance of a ground. The resistance of the soil is dependent upon the moisture content. Electrodes should be long enough to penetrate a relatively permanent moisture level and should extend well below the frost line. Make periodic earth resistance measurements, preferably at times when the soil can be expected to have the least moisture.

You need to test the ground rod installation to be sure it meets the requirement for minimum earth resistance. Use the earth resistance tester to perform the test. You should make this test before you connect the ground cable to the ground rod.

When ground resistances are too high, they may be reduced by one of the following methods:

- Using additional ground rods is one of the best means of reducing the resistance to ground; for example, the combined resistance of two rods properly spaced and connected in parallel should be 60 percent of the resistance of one rod; the combined resistance of three rods should be 40 percent of that of a single rod.

- Longer rods are particularly effective where low-resistance soils are too far below the surface to be reached with the ordinary length rods. The amount of improvement from the additional length on the rods depends on the depth of the low-resistance soils. Usually, a rather sharp decrease in the resistance measurements is noticeable when the rod has been driven to a low-resistance level.
- Treating the soil around ground rods is a reliable and effective method for reducing ground resistance and is particularly suitable for improving high resistance ground. The treatment method is advantageous where long rods are impractical because of rock strata or other obstructions to deep driving. There are two practical ways of accomplishing this result, as shown in *Figure 6-10*. Where space is limited, a length of tile pipe is sunk in the ground a few inches from the ground rod (*Figure 6-10*, view A) and tilled to within 1 foot or so of the ground level with the treatment chemical. Examples of suitable noncorrosive materials are magnesium sulfate, copper sulfate, and ordinary rock salt. The least corrosive is magnesium sulfate, but rock salt is cheaper and does the job.
- The second method is applicable where a circular or semicircular trench can be dug around the ground rod to hold the chemical (*Figure 6-10, View B*). The chemical must be kept several inches away from direct contact with the ground rod to avoid corrosion of the rod. If you wish to start the chemical action promptly, flood the treatment material. The first treatment usually contains 50 to 100 pounds of material. The chemical will retain its effectiveness for 2 to 3 years. Each replenishment of the chemical extends the effectiveness for a longer period so that the necessity for future retreating becomes less and less frequent.
- A combination of methods may be advantageous and necessary to provide desired ground resistance. A combination of multiple rods and soil treatment is effective and has the advantages of both of these methods; multiple long rods are effective where conditions permit this type of installation.

After you are sure you have a good ground, connect the clamp and the ground cable to the top ground rod section (*Figure 6-10*, View B), and secure the connection by tightening the screw.

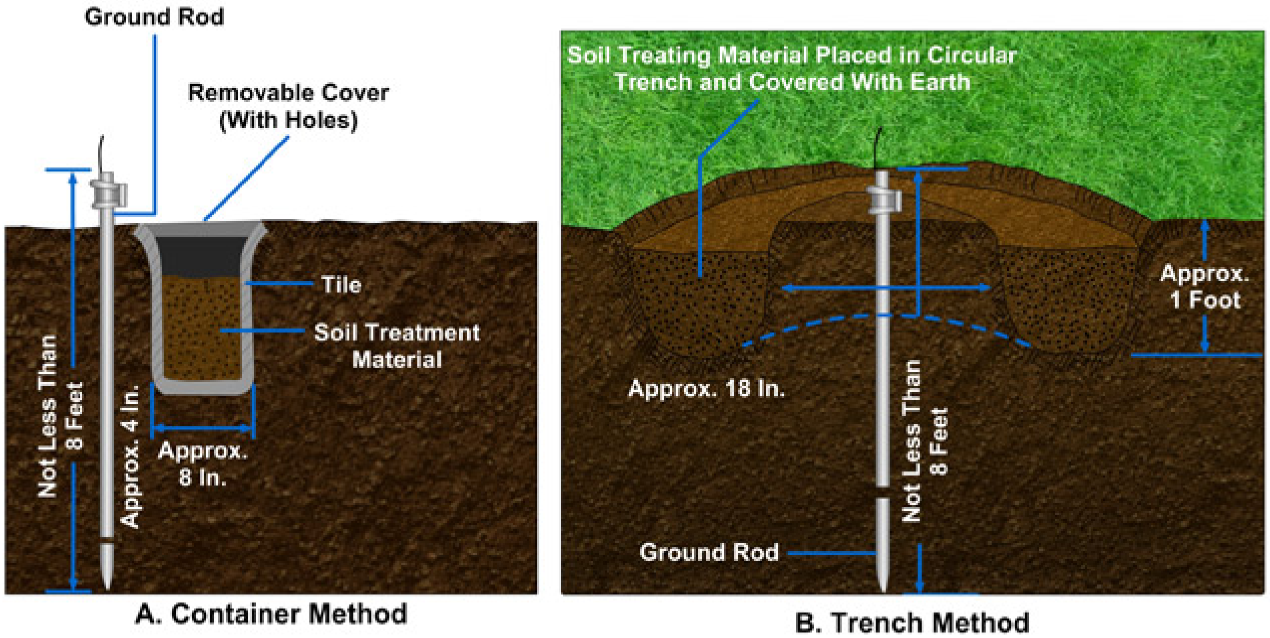

Figure 6-10 – Methods of soil treatment for lowering of ground resistance.

3.5.2 Grounding Connections

A typical generator set is outlined in *Figure 6-11*, showing the load cables and output load terminals.

WARNING

Before attempting to connect the load cables to the load terminals of a generator set, make sure the set is not operating and there is no input to the load.

Refer to *Figure 6-11* as you follow this procedural discussion for making load connections.

1. Open the access door and disconnect the transparent cover by loosening six quick-release fasteners. Remove the wrench clipped to the cover.

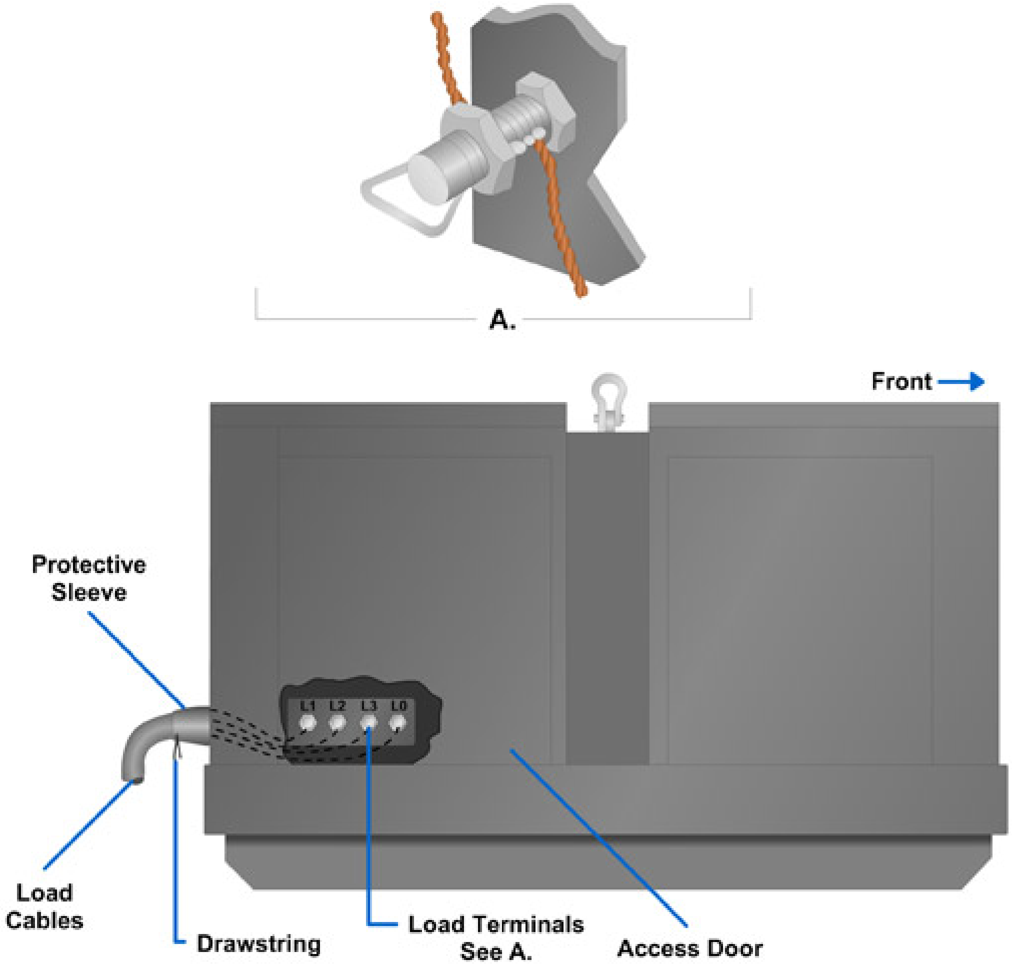

Figure 6-11 – Load cable connections.

NOTE

Be sure to maintain the proper phase relationship between the cable and the load terminals, that is, A0 to L1, B0 to L2, and so forth.

2. Attach the load cables in the following order: L0, L3, L2, and L1 as specified in step 3 below.
3. Insert the load cables through the protective sleeve. Attach the cables to their respective load terminals, one cable to each terminal, by inserting the cable in the terminal slot and tightening the terminal nut with the wrench that was clipped to the transparent cover. Install the wrench on the cover and install the cover.
4. Tighten the drawstring on the protective sleeve to prevent the entry of foreign matter through the hole around the cable.

You may convert the voltage at the load terminals to 120/208 volts or 240/416 volts by properly positioning the voltage change board (*Figure 6-6*). The board is located directly above the load terminal board.

The procedure for positioning the voltage change board for the required output voltage is as follows:

1. Disconnect the transparent cover by loosening the six quick-release fasteners.
2. Remove the 12 nuts from the board. Move the change board up or down to align the change board arrow with the required voltage arrow. Tighten the 12 nuts to secure the board.
3. Position and secure the transparent cover with the six quick-release fasteners and close the access door.

3.5.3 Generator Connections

When you install a power plant that has a dual voltage alternator unit, make certain that the stator coil leads are properly connected to produce the voltage required by the equipment.

Proper grounding is also a necessity for personnel safety and for prevention of unstable, fluctuating generator output.

3.5.3.1 Internal Leads

The voltage changeover board permits reconnection of the generator phase windings to give all specified output voltages. One end of each coil of each phase winding runs from the generator through an instrumentation and a static exciter current transformer to the reconnection panel. This routing assures current sensing in each phase regardless of voltage connection at the reconnection board assembly. The changeover board assembly is equipped with a voltage change board to facilitate conversion to 120/208 or 240/416 generator output voltage. Positioning of the voltage change board connects two coils of each phase in series or in parallel. In parallel, the output is 120/208; in series, the output is 240/416 volts AC. The terminals on the changeover board assembly for connection to the generator loads are numbered according to the particular coil end of each phase of the generator to ensure proper connections.

Remember, you are responsible for the proper operation of the generating unit; therefore, proceed with caution on any reconnection job. Study the wiring diagrams of the plant and follow the manufacturer's instructions to the letter. Before you start the plant up and close the circuit breaker, double-check all connections.

3.5.3.2 Grounding

It is imperative to solidly ground all electrical generators operating at 600 volts or less. The ground can be, in order of preference, an underground metallic water piping system, a driven metal rod, or a buried metal plate. A ground rod has to have a minimum diameter of 5/8 inch if solid and 3/4 inch if pipe, and it has to be driven to a minimum of 8 feet. A ground plate has to be a minimum of 2 square feet and be buried at a minimum depth of 2 l/2 feet. For the ground lead, use No. 6 AWG copper wire and bolt or clamp it to the rod, plate, or piping system. Connect the other end of the ground lead to the generator set ground stud.

The National Electrical Code® states that a single electrode consisting of a rod, pipe, or plate that does not have a resistance to ground of 25 ohms or less will be augmented by additional electrodes. Where multiple rod, pipe, or plate electrodes are installed to meet the requirements, they are required to be not less than 6 feet apart.

It is recommended that you perform an earth resistance test before you connect the generator to ground. This test will determine the number of ground rods required to meet the requirements, or the necessity of constructing a ground grid.

3.5.3.3 Feeder Cable Connections

While the electric generator is being installed and serviced, a part of your crew can connect it to the load. Essentially, this connection consists of running wire or cable from the generator to the load. At the load end, the cable is connected to a distribution terminal. At the generator end, the cable is connected either to the output terminals of a main circuit breaker or a load terminal board. Before running the wires and making the connections, do the following:

- Determine the correct size of wire or cable to use.
- Decide whether the wire or cable will be buried, carried overhead on poles, or run in conduit.
- Check the generator lead connections of the plant to see that they are arranged for the proper voltage output.

3.5.3.3.1 Cable Selection

If you use the wrong size conductor in the load cable, various troubles may occur. If the conductor is too small to carry the current demanded by the load, it will heat up and possibly cause a fire or an open circuit. Even though the conductor is large enough to carry the load current safely, its length might result in a lumped resistance that produces an excessive voltage drop. An excessive voltage drop results in a reduced voltage at the load end. This voltage drop should not exceed 3 percent for power loads, 3 percent for lighting loads, or 6 percent for combined power and lighting loads.

Select a feeder conductor capable of carrying 150 per cent of rated generator amperes to eliminate overloading and voltage drop problems. Refer to the National Electrical Code® tables for conductor ampacities. These tables are 310-16, 310-17, 310-18, and 310-19. Also refer to the notes to ampacity tables following table 310-19.

3.5.3.3.2 Cable Installation

The load cable may be installed overhead or underground. In an emergency installation, time is the important factor. It may be necessary to use trees, pilings, 4 by 4s, or other temporary line supports to complete the installation. Such measures are temporary; eventually, you will have to erect poles and string the wire or bury it underground. If the installation is near an airfield, it may be necessary to place the wires underground at the beginning. Wire placed underground should be direct burial, rubber-jacketed cable: otherwise, it will not last long.

Direct burying of cable for permanent installation calls for a few simple precautions to ensure uninterrupted service. They are as follows:

- Dig the trench deep enough to bury the cable at least 18 inches (24 inches in traffic areas and under roadways) below the surface of the ground to prevent disturbance of the cable by frost or subsequent surface digging.
- After laying the cable and before backfilling, cover it with soil free from stones, rocks, and so forth. That will prevent the cable from being damaged in the event the surrounding soil is disturbed by flooding or frost heaving.

4.0.0 GENERATING PLANT OPERATIONS

When you are in charge of a generating station, you will be responsible for scheduling around-the clock watches to ensure a continuous and adequate supply of electrical power. Depending on the number of operating personnel available, the watches are evenly divided over the 24-hour period. A common practice is to schedule 6-hour watches, or they may be stretched to 8-hour watches without working undue hardship on the part of the crew members. Avoid watches exceeding 8 hours, however, unless emergency conditions dictate their use.

The duties assigned to the personnel on generator watches can be grouped into three main categories: (1) operating the equipment, (2) maintaining the equipment, and (3) keeping the daily operating log. Operating and maintaining the generating equipment will be covered in the succeeding sections of this chapter, so for the present you can concentrate on the importance of the third duty of the station operator—keeping a daily operating log.

The number of operating hours are recorded in the generating station log. The log serves as a basis for determining when a particular piece of electrical equipment is ready for inspection and maintenance. The station log can be used in conjunction with previous logs to spot gradual changes in equipment condition that ordinarily are difficult to detect in day to day operation. It is particularly important that you impress upon your watch standers the necessity for taking accurate readings at periods specified by local operating conditions.

Ensure that watch standers keep their spaces clean and orderly. Impress on them the importance of keeping tools and auxiliary equipment in their proper places when not in use. Store clean waste and oily waste in separate containers. Oily waste containers are required to be kept covered. Care given to the station floor will be governed by its composition. Generally, it should be swept down each watch. Any oil or grease that is tracked around the floor should be removed at once.

4.1.0 Generator Watch

While standing a generator watch, you must be alert and respond quickly when you recognize a problem. You might not have control of every situation but at least you can secure the generator and prevent serious problems.

Your primary purpose is to produce power in a safe and responsible manner. You may notice maintenance or repair actions that need to be rectified but do not require immediate attention and do not affect your watch. Make note of these problems so that they will be taken care of by the repair crew. In addition, concentrate on doing your job properly, and your efforts will pay off.

A generator watch involves performing operator maintenance, maintaining the operator’s log, operating a single generator, or operating paralleled generators.

4.2.0 Operator’s Log

The operator’s log (also called the station log) is a complete daily record of the operating hours and conditions of the generator set. The log must be kept clean and neat. The person who signs the log for a watch must make any corrections or changes to entries for that watch.

The log serves as a basis for determining when a particular piece of electrical equipment is ready for inspection and maintenance. Current and previous logs can be compared to spot gradual changes in equipment condition. These changes might not otherwise be detected in day-to-day operation.

Note defects discovered during operation of the unit for future correction; such correction to be made as soon as operation of the generator set has ceased.

Making accurate periodic recordings is particularly important. The intervals of these recordings will be based on local operating conditions.

The form used for log entries varies with the views of the supervisory personnel in different plants, and there is no standard form to be followed by all stations. Regardless of form, any log must describe the hourly performance not only of the generators but also of the numerous indicating and controlling devices.

Figure 6-12 shows one type of log that may be kept on the generator units of a power plant. This is only a suggested form, of course, and there may be many other forms at your generating station to keep records on.

SUGGESTED FORM OF PLANT OPERATION LOG

Date	Time	UNIT NO. 1785			UNIT NO. 942			UNIT NO. 3465			REMARKS
		Speed Time Meter	Volts	Ampere	Speed Time Meter	Volts	Ampere	Speed Time Meter	Volts	Ampere	
2/8/93	1600	195.0	220	58	302.0	52	220	934.0	220	27	Started up
—	1730	196.5									added 2qts oil to #1785
—	2100	200.0	221	54	307.0	49	221				shut down #3465

OPERATOR ____________________

Figure 6-12 – Typical generating station operator's log.

4.3.0 Plant Equipment

Setting up a power generator is only one phase of your job. After the plant is set up and ready to go, you will be expected to supervise the activities of the operating personnel of the generating station. In this respect, you should direct your supervision toward one ultimate goal-to maintain a continuous and adequate flow of electrical power to meet the demand. That can be accomplished if you have a thorough knowledge of how to operate and maintain the equipment and a complete understanding of the station's electrical systems as a whole. Obviously, a thorough knowledge of how to operate and maintain the specific equipment found in the generating station to which you are assigned cannot be covered here; however, general information will be given. It will be up to you to supplement this information with the specific instructions given in the manufacturers' instruction manuals furnished with each piece of equipment.

Similarly, you can gain familiarity with the station's electrical system as a whole only by studying information relating specifically to that installation. This information can be found to some extent in the manufacturer's instruction manuals. You can obtain the greater part of it from the station's electrical plans and wiring diagrams. Remember, however, to supplement your study of the electrical plans and diagrams with an actual study of the generating station's system. That way, the generators, switchgear, cables, and other electrical equipment are not merely symbols on a plan but physical objects whose location you definitely know and whose functions and relation to the rest of the system you thoroughly understand.

4.4.0 Single Plant Operation

Connecting an electric plant to a de-energized bus involves two general phases: (1) starting the diesel engine and bringing it up to rated speed under control of the governor and (2) operating the switchboard controls to bring the power of the generator onto the bus.

Different manufacturers of generating plants require the operator to perform a multitude of steps before starting the prime mover; for example, if a diesel engine is started by compressed air, the operator would have to align the compressed air system. This alignment would not be necessary if the engine is of the electric-start type. It is important that you, as the plant supervisor, establish a prestart checklist for each generating plant. The prestart checklist provides a methodical procedure for confirming the operational configuration of the generating plant; following this procedure assures that all systems and controls are properly aligned for operation.

The checklist should include, but is not limited to, the following:

1. Align ventilation louvers.
2. Check lube oil, fuel oil, and cooling water levels.
3. Ensure battery bank is fully charged.
4. Align electrical breakers and switches for proper operation of auxiliary equipment.
5. Check control panel and engine controls.
6. Select the proper operating position for the following controls for single plant operation.
    - Voltage regulator switch to UNIT or SINGLE position.
    - Governor switch to ***ISOCHRONOUS*** or SINGLE position.

NOTE

Adjust hydraulic governor droop position to 0.

- Voltage regulator control switch to AUTO position.

Complete the prestart checklist in sequence before you attempt to start the generating plant.

Start the generating plant and adjust the engine revolutions per minute (rpm) to synchronous speed. Adjust the voltage regulator to obtain the correct operating voltage.

Set the synchronizing switch to the ON position and close the main circuit breaker. Adjust the frequency to 60 hertz with the governor control switch. Perform hourly operational checks to detect abnormal conditions and to ensure the generating set is operating at the correct voltage and frequency.

4.4.1 Operating Procedures for Single Generator Sets

The following operating procedures are general procedures for operating a single generator unit. Some procedures will vary with different types of generators. Study carefully the recommendations in the manufacturer's manual for the generator you are to operate. Learn about the capabilities and limitations of your machine(s). In the event of a problem, you will know what action is required to lessen the effects of the problem. You or your senior should make a checklist of operating procedures from the manual and post it near the generator.

The steps below will cover starting and operating a typical diesel-driven generator set. (This set uses a DC powered motor for starting the diesel engine.) These steps will also cover applying an electrical load.

4.4.1.1 Starting the Generator Set

Proceed as follows to start the typical generator set:

WARNING

Do not operate the generator set unless it has been properly grounded. Electrical faults (such as leakage paths) in the generator set, feeder lines, or load equipment can cause injury or death by electrocution.

Before operating the set for the first time, ensure that service procedures were performed upon its receipt according to the manufacturer's literature. See also that all preventive maintenance checks have been performed. The voltage change board must be adjusted for the required voltage (*Figure 6-13*).

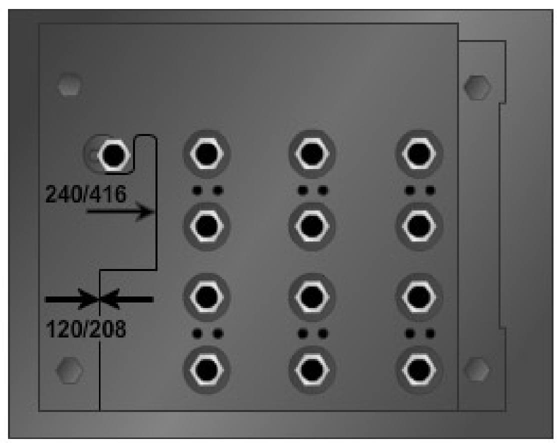

Figure 6-13 – Typical changeover board assembly.

1. Open the CONTROL CUBICLE and AIR INTAKE DOORS (*Figure 6-14*). Close the HOUSING PANEL (ACCESS) DOORS.
2. Set the FUEL TRANSFER VALVE (*Figure 6-14*) to the desired source of fuel, preferably the auxiliary tank, if it is connected.

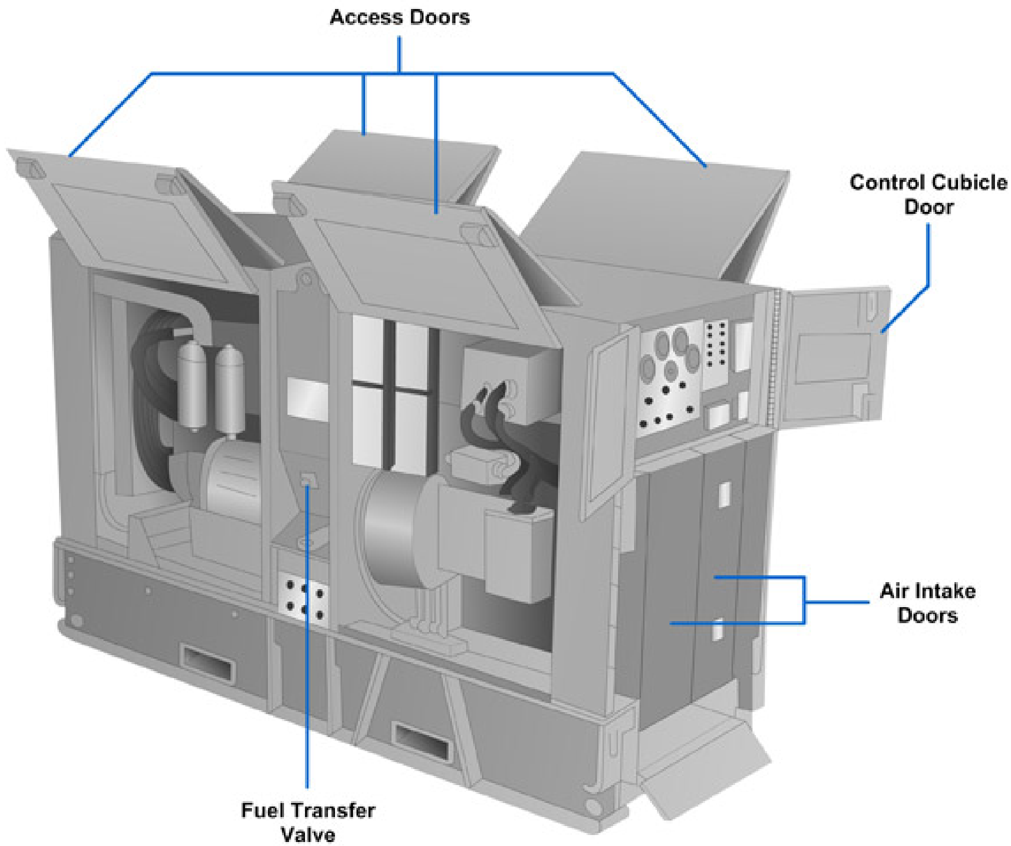

Figure 6-14 – Generator set, left rear, three quarters view.

NOTE

Refer to *Figure 6-15* for the CONTROL CUBICLE, FAULT INDICATOR PANEL, DC CONTROL CIRCUIT BREAKER, and ENGINE MANUAL SPEED CONTROL. Notice that the control cubicle is divided into an engine section and a generator section.

3. Set the PARALLEL OPERATION – SINGLE UNIT OPERATION select switch (located in the GENERATOR section of the CONTROL CUBICLE) to SINGLE UNIT OPERATION.
4. Set the VOLTAGE ADJUST – INCREASE control to the lower half of the adjustment range.
5. Depress the DC CONTROL CIRCUIT BREAKER (located to the lower right of the CONTROL CUBICLE) to ON.
6. Set the START – STOP –RUN switch (located in the ENGINE section of the CONTROL CUBICLE) to RUN.
7. Set and hold the TEST or RESET switch (on the FAULT INDICATOR PANEL) in the UP position. Check each fault indicator light that is on and replace defective lamps or fuses.
8. Allow the TEST or RESET switch to return to the mid position. Each fault indicator light, with the exception of the LOW OIL Pressure light, should go out. When the engine has started, the LOW OIL PRESSURE light should also go out.

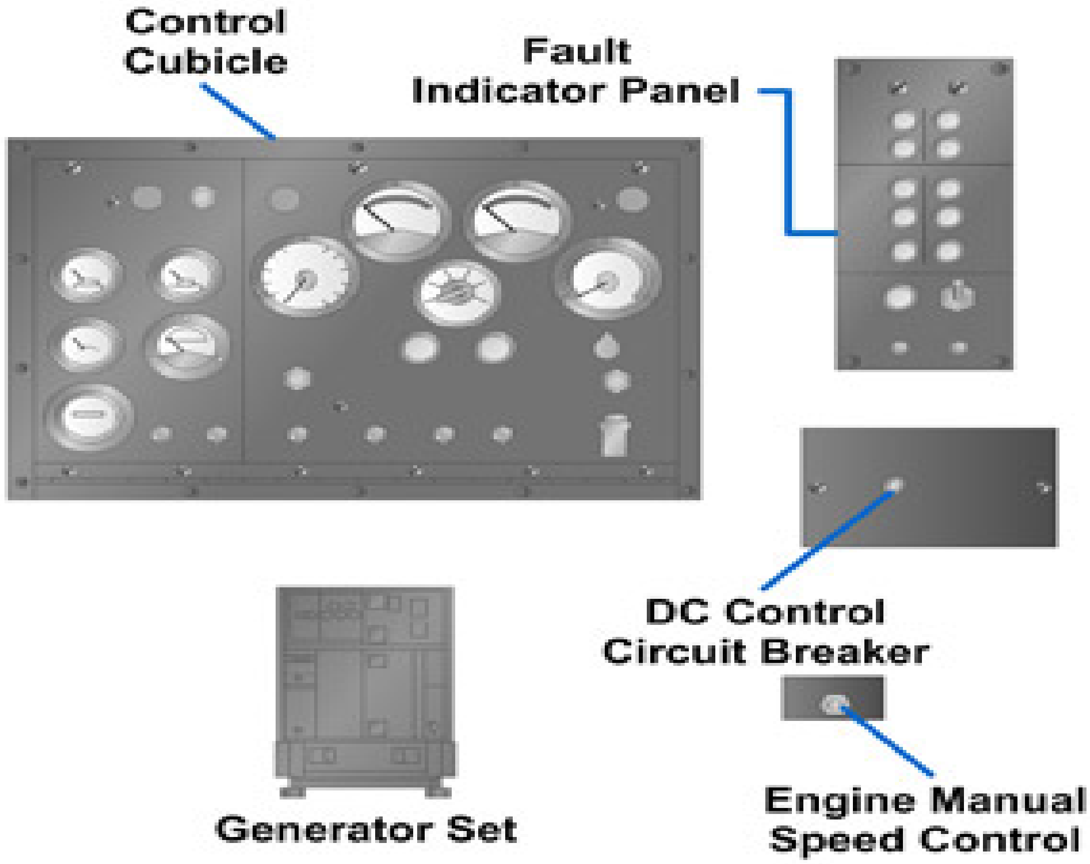

Figure 6-15 – Control cubicle, controls, and indicators.

NOTE

If the NO FUEL light stays lit, refill the set or auxiliary tank. Position the BATTLE SHORT switch (CONTROL CUBICLE) to ON (the fuel pump will run to fill the day tank). Set the TEST or RESET switch to the UP position and then release it; the NO FUEL light should go out when the switch handle is released.

9. Set the CKT BRK CLOSE – OPEN switch (CONTROL CUBICLE) to OPEN.
10. Push and release the AIR CLEANER CONDITION indicator, BATTLE SHORT indicator, and CKT BKR indicator. Each indicator light should go on as the indicator is pushed and go out when the indicator is released.
    a. If the AIR CLEANER CONDITION indicator remains lit, the air cleaner must be serviced.
    b. If the CKT BKR indicator remains on after you set the CKT BRK switch to OPEN, you cannot continue the procedure. The circuit breaker must function properly. The generator cannot be used until the problem is corrected.
11. Depress the lock button on the ENGINE MANUAL SPEED CONTROL (located below the DC CONTROL CIRCUIT BREAKER), and set the control.

⚠ CAUTION ⚠

DO not crank the engine in excess of 15 seconds at a time. Allow the starter to cool a minimum of 3 minutes between cranking.

WARNING

Operation of this equipment presents a noise hazard to personnel in the area. The noise level exceeds the allowable limits for unprotected personnel. Wear earmuffs or earplugs.

12. Set and hold the START – STOP – RUN switch to the START position until the engine starts. As the engine starts, observe the following:
    a. The OIL PRESSURE gauge indicates at least 25 pounds per square inch gauge (psig).
    b. The VOLTS AC meter indicates the presence of voltage.
    c. The LOW OIL PRESSURE indicator light on the FAULT INDICATOR PANEL goes out.
13. Release the START – STOP – RUN switch. Position the switch to RUN.

4.4.1.2 Operating the Generator Set

The procedures for operating a single generator set (single unit) are as follows:

1. Ensure that the PARALLEL OPERATION – SINGLE UNIT OPERATION switch is set to SINGLE UNIT OPERATION.
2. Position the AMPS – VOLTS selector switch to the required position. Rotate the VOLTAGE ADJUST control to obtain the required voltage. Read the voltage from the VOLTS AC meter.
3. Depress the locking button and slide the ENGINE MANUAL SPEED CONTROL in or out to obtain the approximate rated frequency; rotate the vernier knob (the knob on the control) clockwise or counterclockwise to obtain the rated frequency.

NOTE

If necessary, the load may be applied immediately.

4. Operate the engine for at least 5 minutes to warm it up.
5. Apply the load by holding the CKT BRK switch (on the CONTROL CUBICLE) to CLOSE until the CKT BRK indicator lights go out. Then release the switch.
6. Observe the readings from the VOLTS AC meter and the HERTZ (FREQUENCY) meter. The voltage readings should be 120/208 to 240/416 volts AC (depending on the positions of the AMPS-VOLTS select switch and the voltage change board). Let's say, for example, that you positioned the voltage change board for 120/208 volts before you started the generator set. When you position the AMPS-VOLTS selector switch to L2-L0 VOLTS/L2 AMPS while the generator is operating, the VOLTS AC meter should indicate 120 volts. The PERCENT RATED CURRENT meter will indicate the percent rated current (not more than 100 percent) between generator line 2 and neutral. The HERTZ (FREQUENCY) meter should indicate 50 or 60 hertz. The KILOWATTS meter should indicate no more than 100 percent with the HERTZ (FREQUENCY) meter showing 60 hertz. Readjust the voltage and frequency, if necessary.
7. Observe the KILOWATTS meter. If the meter indicates that more than the rated kilowatts are being consumed, reduce the load.

8. Rotate the AMPS-VOLTS selector switch to each phase position and monitor the PERCENT RATED CURRENT meter. If it indicates more than the rated load for any phase position, reduce or reapportion the load.
9. Periodically (not less than once per hour), monitor the engine and generator indicators to ensure their continued operation.
10. Perform any preventive checks.

When in operation, monitor the generator set periodically (at least once an hour) for signs indicating possible future malfunctions.

After the warm-up, the lubricating oil pressure should remain virtually constant. Check and record the level of lubricating oil while the engine is running normally. If any significant changes occur in the oil pressure, notify maintenance personnel. Check and record the coolant temperature of the normally running engine. Notify maintenance personnel if the coolant temperature changes significantly.

Learn the sounds of a normally running generator set so that any unusual sounds indicating the possible start of a malfunction may be detected early enough to avoid major damage.

Stop the operation immediately if a deficiency that would damage the equipment is noted during operation.

4.5.0 Parallel Plant Operation

If the load of a single generator becomes so large that it exceeds the generator's rating, add another generator in parallel to increase the power available for the generating station. Before two AC generators can be paralleled, the following conditions have to be fulfilled:

- Their terminal voltages have to be equal.
- Their frequencies have to be equal.
- Their voltages have to be in phase.

When two generators are operating so that the requirements are satisfied, they are said to be in synchronism. The operation of getting the machines into synchronism is called synchronizing.

Generating plants may be operated in parallel on an isolated bus (two or more generators supplying camp or base load) or on an infinite bus (one or more generators paralleled to a utility grid).

One of the primary considerations in paralleling generator sets is achieving the proper division of load. That can be accomplished by providing the governor of the generator with speed droop. That would result in a regulation of the system. The relationship of REGULATION to LOAD DIVISION is best explained by referring to a speed versus load curve of the governor. For simplicity, we will refer to the normal speed as 100 percent speed and full load as 100 percent load. In the controlled system, we will be concerned with two types of governor operations: isochronous and speed droop.

The operation of the isochronous governor (0 percent speed droop) can be explained by comparing speed versus load. as shown in *Figure 6-16*. If the governor were set to maintain the speed represented by line A and connected to an increasing isolated load, the speed would remain constant. The isochronous governor will maintain the desired output frequency regardless of load changes if the capacity of the engine is not exceeded.

The speed-droop governor (100 percent speed droop) has a similar set of curves but they are slanted, as shown in *Figure 6-17*. If a speed-droop governor was connected to an increasing isolated load, the speed would drop (Line A. *Figure 6-17*) until the maximum engine capacity is reached.

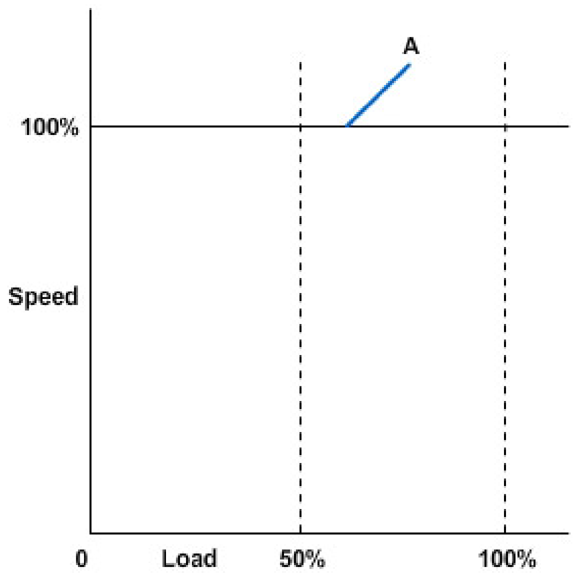

Figure 6-16 – Isochronous governor curve.

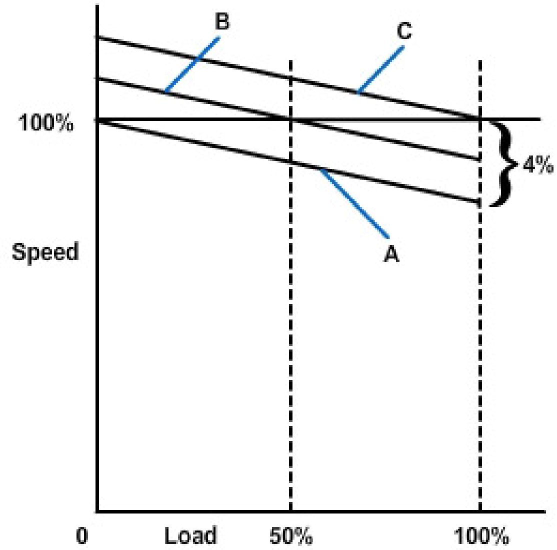

Figure 6-17 – Speed droop governor curve.

Now let's imagine that we connect the speed droop governor (slave machine) to a utility bus so large that our engine cannot change the bus frequency (an infinite bus). Remember that the speed of the engine is no longer determined by the speed setting but by the frequency of the infinite bus. In this case, if we should change the speed setting, we would cause a change in load, not in speed. To parallel the generator set, we must have a speed setting on line A (*Figure 6-17*) at which the no-load speed is equal to the bus frequency. Once the set is paralleled, if we increase the speed setting to line B, we do not change the speed, but we pick up approximately a half-load. Another increase in speed setting to line C will fully load the engine. If the generator set is fully loaded and the main breaker is opened, the no-load speed would be 4 percent above synchronous speed. This governor would be defined as having 4 percent speed droop.

Paralleling an isochronous governor to an infinite bus would be impractical because any difference in speed setting would cause the generator load to change constantly. A speed setting slightly higher than the bus frequency would cause the engine to go to full-load position. Similarly, if the speed setting were slightly below synchronous speed, the engine would go to no load position.

Set speed droop on hydraulic governors by adjusting the speed-droop knob located on the governor body. Setting the knob to position No. 5 does not mean 5 percent droop. Each of the settings on the knob represents a percentage of the total governor droop. If the governor has a maximum of 4 percent droop. the No. 5 position would be 50 percent of 4 percent droop. Set speed droops on solid-state electronic governors by placing the UNIT-PARALLEL switch in the PARALLEL position. The governor speed droop is factory set, and no further adjustments are necessary.

4.5.1 Isolated Bus Operation

In the following discussion, assume that one generator, called the master machine, is operating and that a second generator, called the slave machine, is being synchronized to the master machine. Governor controls on the master generator should be set to the ISOCHRONOUS or UNIT position. The governor setting on the slave generator must be set to the PARALLEL position.

NOTE

The hydraulic governor droop setting is an approximate value. Setting the knob to position No. 5 will allow you to parallel and load the generator set. Minor adjustments may be necessary to prevent load swings after the unit is operational.

When you are paralleling in the droop mode with other generator sets, the governor of only one set may be in the isochronous position; all others are in the droop position. The isochronous set (usually the largest capacity set) controls system frequency and immediately responds to system load changes. The droop generator sets carry only the load placed on them by the setting of their individual speed controls. Both voltage regulators should be set for parallel and automatic operation.

Bring the slave machine up to the desired frequency by operating the governor controls. It is preferable to have the frequency of the slave machine slightly higher than that of the master machine to assure that the slave machine will assume a small amount of load when the main circuit breaker is closed. Adjust the voltage controls on the slave machine until the voltage is identical to that of the master machine. Thus two of the requirements for synchronizing have been met: “frequencies are equal and terminal voltages are equal.”

There are several methods to check generator phase sequence. Some generator sets are equipped with phase sequence indicator lights and a selector switch labeled “GEN” and “BUS.” Set the PHASE SEQUENCE SELECTOR SWITCH in the BUS position, and the “1-2-3” phase sequence indicating light should light. (The same light must light in either GEN or BUS position.) If “3-2-1” phase sequence is indicated, shut down the slave machine, isolate the load cables, and interchange two of the load cables at their connection to the load terminals.

Another method to verify correct phase sequence is by using the synchronizing lights. When the synchronizing switch is turned on, the synchronizing lights will start blinking. If the synchronizing lights blink on simultaneously and off simultaneously, the voltage sequences of the two machines are in phase. The frequency at which the synchronizing lights blink on and off together indicates the different frequency output between the two machines. Raise or lower the speed of the slave machine until the lights blink on together and off together at the slowest possible rate. If the synchronizing lights are alternately blinking (one on while the other is off), the voltage sequence of the two machines is not in phase. Correct this condition by interchanging any two of the three load cables connected to the slave machine.

Some of the portable generators being placed in the Table of Allowances (TOA) are equipped with a permissive paralleling relay. This relay, wired into the main breaker control circuit, prevents the operator from paralleling the generator until all three conditions have been met.

Now that all three paralleling requirements have been met, the slave machine can be paralleled and loaded.

If you use a synchroscope, adjust the frequency of the slave machine until the synchroscope pointer rotates clockwise slowly through the ZERO position (twelve o'clock). Close the main circuit breaker just before the pointer passes through the ZERO position. To parallel using synchronizing lights, wait until the lamps are dark; then, while the lamps are still dark, close the main circuit breaker and turn off the synchronizing switch.

After closing the main breaker, check and adjust the load distribution by adjusting the governor speed control. Maintain approximately one-half load on the master machine by manually adding or removing the load from the slave machine(s). The master machine will absorb all load changes and maintain correct frequency unless it becomes overloaded or until its load is reduced to zero.

The operator also must ensure that all generating sets operate at approximately the same power factor (PF). PF is a ratio, or percentage, relationship between watts (true power) of a load and the product of volts and amperes (apparent power) necessary to supply the load. PF is usually expressed as a percentage of 100. Inductive reactance in a circuit lowers the PF by causing the current to lag behind the voltage. Low PFs can be corrected by adding capacitor banks to the circuit.

Since the inductive reactance cannot be changed at this point, the voltage control rheostat has to be adjusted on each generator to share the reactive load. This adjustment has a direct impact on the generator current, thus reducing the possibility of overheating the generator windings.

PF adjustment was not discussed in the "Single Plant Operation" section because a single generator has to supply any true power and/or reactive load that may be in the circuit. The single generator must supply the correct voltage and frequency regardless of the PF.

4.5.2 Infinite Bus Operation

Paralleling generator sets to an infinite bus is similar to the isolated bus procedure with the exception that all sets will be slave machines. The infinite bus establishes the grid frequency; therefore, the governor of each slave machine has to have speed droop to prevent constant load changes.

4.5.3 Operating Procedures for Paralleling Generators

This section will include procedures for paralleling generators, removing a set from parallel operations, and stopping generator set operation.

NOTE

These procedures assume that one generator set is on line (operating and connected to the distribution feeder lines through the switchgear). The set that is to be paralleled is designated the incoming set (*Figure 6-18*).

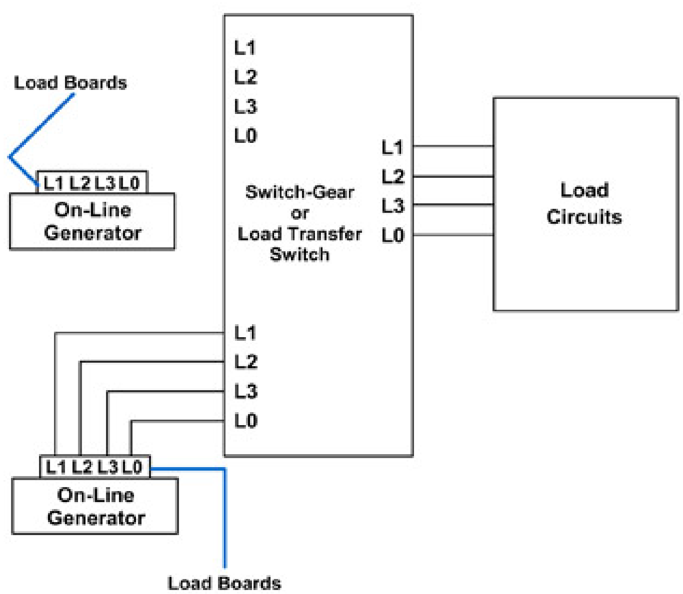

Figure 6-18 – Parallel operation connection diagram.

CAUTION

When you are operating generator sets in parallel, they must have the same output voltage, frequency, phase relation, and phase sequence before they can be connected to a common distribution bus. Severe damage may occur to the generator sets if these requirements are not met.

Adjusting the engine speed of the incoming set while observing the output frequency and the SYNCHRONIZING LIGHTS (*Figure 6-15*) will bring the phase and frequency into exact agreement. As the phase and frequency approach the same value, the SYNCHRONIZING LIGHTS will gradually turn on and off. When the blinking slows to a rate of once per second or slower, close the main circuit breaker of the incoming set while the SYNCHRONIZING LIGHTS are dark. The phase sequence relates to the order in which the generator windings are connected. If the phase sequence is not correct, the SYNCHRONIZING LIGHTS will not blink on and off together. When the incoming set is first connected to the load through the appropriate switchgear (*Figure 6-18*), you should observe one of four occurrences. When the phase sequence, voltage, frequency, phase, and engine performance are the same, the changeover will be smooth with only the slightest hesitation in engine speed; if each output is slightly out of phase, one of the engines will shudder at the point of changeover; if the phase sequence or voltage levels are incorrect, the reverse power relay will trip on one of the generator sets and open its main circuit breaker contactors; if the incoming generator set loses speed significantly or almost stalls, the incoming engine may be defective.

CAUTION

Should either generator set lose speed, buck, or shudder when the incoming set is connected to the distribution feeder lines, immediately flip the CKT BRK switch of the incoming set to open, and then recheck the paralleling set-up procedures.

WARNING

When performing step 1, make certain that the incoming set is shut down and that there are no voltages at the switchgear terminals being connected to the incoming set. Do not take anybody’s word for it! Check it out for yourself! Dangerous and possibly deadly voltages could be present. Take extreme care not to cross the L0 (neutral) with any of the other phases (L1, L2, or L3).

4.5.3.1 Paralleling Procedures

1. Connect the incoming set, as shown in *Figure 6-18*.
2. Make certain that the voltage change board (reconnection board) of the incoming generator is set up for the same output voltage as the online generator.
3. Set CKT BRK switch on the incoming set to OPEN. When the incoming set circuit breaker is open (CKT BRK indicator light will be out), operate the load switchgear so that the on line output voltage is present at the voltage change board of the incoming set.
4. Set the PARALLEL OPERATION-SINGLE UNIT operation switch on both sets to PARALLEL OPERATION.
5. Start the incoming set. The on line set should be in operation already.
6. After a 5 minute warmup, try the VOLTAGE ADJUST control on the incoming set until the output voltages of both sets are equal.

CAUTION

If the synchronizing lights do not blink on and off in unison, the phase sequence is incorrect. Shut down the incoming set and recheck the cabling to and from the incoming set.

7. On the incoming set, position the ENGINE MANUAL SPEED CONTROL until the SYNCHRONIZING LIGHTS blink on and off as slowly as possible.
8. With one hand on the CKT BRK switch, adjust the ENGINE MANUAL SPEED CONTROL vernier knob until the SYNCHRONIZING LIGHTS dim gradually from full on to full off as slowly as possible. Just as the SYNCHRONIZING LIGHTS dim to out, set and hold the CKT BRK switch to close. When the CKT BRK indicator light comes on, release the switch.
9. On both sets, check that the readings of the PERCENT RATED CURRENT meters and KILOWATTS meters are well within 20 percent of each other. If not, increase the engine power of the set with the lower readings (by adjusting the ENGINE MANUAL SPEED CONTROL to increase the speed) until the readings are about equal.

NOTE

The division of the kilowatt load is also dependent on the frequency droop of the two sets and must be adjusted at the next higher level of maintenance. If the current does not divide as described above, adjust the reactive current sharing control located at the right side of the special relay box for equal reading on both percent rated current meters.

10. On the incoming set, readjust the voltage and frequency of the output until it is equal to the output of the on-line set.

4.5.3.2 Removing a Generator Set from parallel Operation

CAUTION

Before removing the generator set(s) from parallel operation, make sure the load does not exceed the full-load rating of the generator set(s) remaining on the line.

1. On the outgoing set, position and hold the CKT BRK switch to OPEN until the CKT BRK indicator light goes out. Release the switch.
2. On the outgoing set, allow the engine to operate with no load for about 5 minutes.
3. On the outgoing set, pull the DC CONTROL CIRCUIT BREAKER to OFF.
4. On the outgoing set, set the START-STOP-RUN switch to STOP.

WARNING

Make certain the outgoing set is shut down and there are no voltages at the switchgear terminals connected to the outgoing set. Do not take anybody's word for it! Check it out for yourself!

5. Disconnect the cables going from the outgoing set to the load switchgear.

4.5.3.3 Stopping Generator Set Operation

1. Set the CKT BRK switch to OPEN until the CKT BRK indicator light goes out, and then release the CKT BRK switch.
2. Allow the engine to cool down by operating at no load for 5 minutes.
3. Set the START-STOP-RUN switch to STOP.
4. Close all generator doors.

4.6.0 Emergency Shutdown

In the event of engine over speed, high jacket water temperature, or low lubricating oil pressure, the engine may shut down automatically and disconnect from the main load by tripping the main circuit breaker. In addition, an indicator may light or an alarm may sound to indicate the cause of shutdown. After an emergency shutdown and before the engine is returned to operation, investigate and correct the cause of the shutdown.

NOTE

It is important to check the safety controls at regular intervals to determine that they are in good working order.

4.7.0 Basic Operating Precautions

The order that you post in the station for the guidance of the watch standers should include a general list of operating rules and electrical safety precautions. **BE SURE YOU ENFORCE THEM!**

The important operating rules are relatively few and simple. They are as follows:

- Watch the switchboard instruments. They show how the system is operating; and they reveal overloads, improper division of kilowatt load or reactive current between generators operating in parallel, and other abnormal operating conditions.
- Keep the frequency and voltage at their correct values. A variation from either will affect, to some extent at least, the operation of the electrical equipment of the base. This result is especially true of such equipment as teletypewriters or electrical clocks. An electrical clock and an accurate mechanical clock should be installed together at the generating station so that the operators can keep the generators on frequency.
- Use good judgment when reclosing circuit breakers after they have tripped automatically; for example, generally the cause should be investigated if the circuit breaker trips immediately after the first reclosure. However, reclosing of the breaker the second time may be warranted if immediate restoration of power is necessary and there was no excessive interrupting disturbance when the breaker tripped. It should be kept in mind, however, that repeated closing and tripping may damage the circuit breaker as well as the overload vault area, thus increasing the repair or replacement work.
- Do not start a plant unless all its switches and breakers are open and all external resistance is in the exciter field circuit.
- Do not operate generators at continuous overload. Record the magnitude and duration of the overload in the log; record any unusual conditions or temperatures observed.

- Do not continue to operate a machine in which there is vibration until the cause is found and corrected. Record the cause in the log.

The electrical safety precautions that should be observed by the station personnel are as follows:

- Treat every circuit, including those as low as 24 volts, as a potential source of danger.
- Except in cases of emergency, never allow work on an energized circuit. Take every precaution to insulate the person performing the work from ground. That may be done by covering any adjacent grounded metal with insulating rubber blankets. In addition, provide ample illumination; cover working metal tools with insulating rubber; station men at appropriate circuit breakers or switches so that the switchboard can be de-energized immediately in case of emergency, and make sure all personnel are qualified to render first aid (including CPR) for electric shock.

Test your Knowledge (Select the Correct Response)

1. Which of the following conditions DOES NOT need to be met for parallel generator operation?

   A. Terminal voltages have to be equal
   B. Frequencies have to be equal
   C. Voltages have to be in phase
   D. Amperages have to be equal

5.0.0 SERVICING GENERATORS

Before the set is operated, it must be serviced. We will use the 60 Kilowatt (kW) generator set as an example for discussing the servicing of the set after you receive it. As you read this discussion, refer to *Figure 6-19* for locating fill and drain points and drain valves.

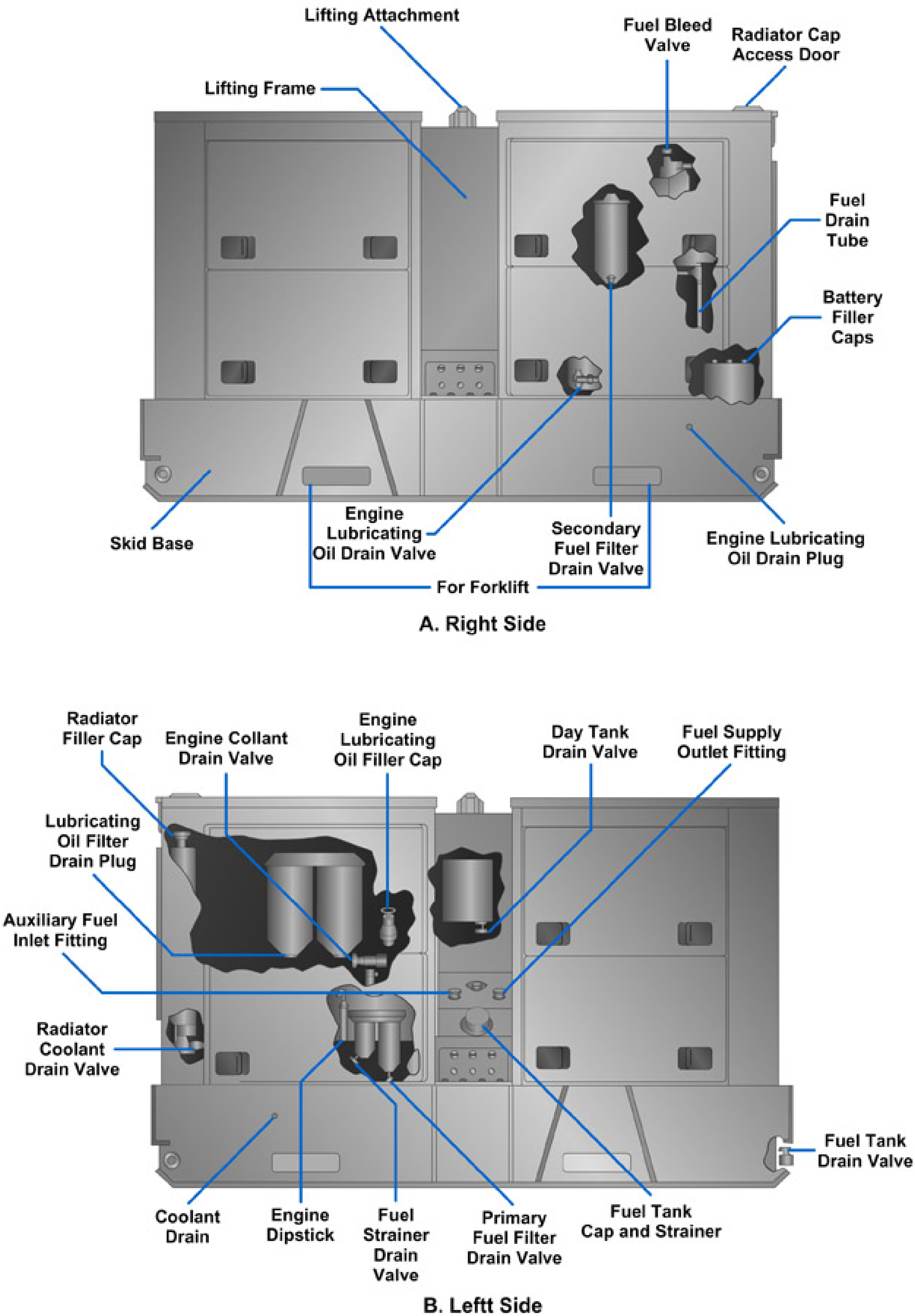

Figure 6-19 – Typical 60 kW generator set.

5.1.0 Batteries

All 5 kW through 750 kW generator sets are furnished with dry charged batteries less the electrolyte. Battery electrolyte must be requisitioned separately.

You must be cautious when installing, activating, or maintaining batteries. Before we discuss connecting and servicing batteries, let's look at a few safety points you must know about.

WARNING

Do not smoke or use an open flame in the vicinity of batteries when servicing them. Batteries generate hydrogen, a highly explosive gas. When removing batteries, always remove both negative cables before removing the positive cables (*Figure 6-20*).

Battery electrolyte contains sulfuric acid and can cause severe burns. It is highly toxic to the skin, eyes, and respiratory tract. Skin, eyes, and face (chemical splash goggles, face shields) and respiratory protection are required. Whenever electrolyte comes into contact with the body, the eyes, or the clothing, you must rinse immediately with clean water, remove contaminated clothing, and then go to sickbay or the medical clinic for a thorough examination.

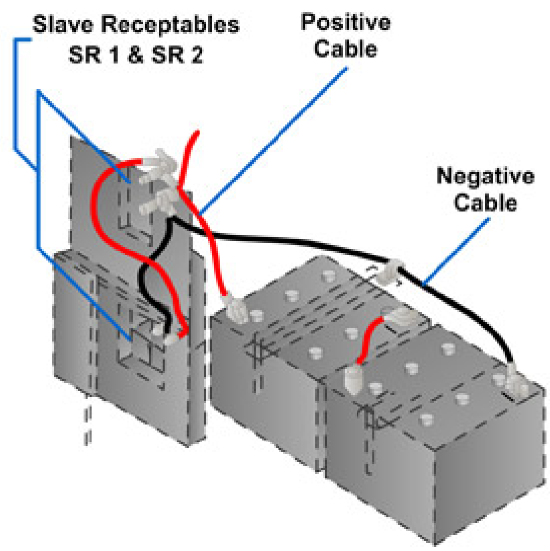

Figure 6-20 – Battery cable connection and slave receptacles.

The 60 kW generator set is equipped with two 12 volt, 100 ampere-hour batteries. The batteries are located under the radiator (*Figure 6-19*, View A) on a roll out tray (*Figure 6-21*). They are connected in series to supply 24 volts dc for starting the generator set and operating direct current components. Two slave receptacles (*Figure 6-20*), connected in parallel, permit easy connection to the batteries to supply or obtain battery power. As we discuss activating the batteries, refer to steps 1 through 3 and *Figure 6-21*.

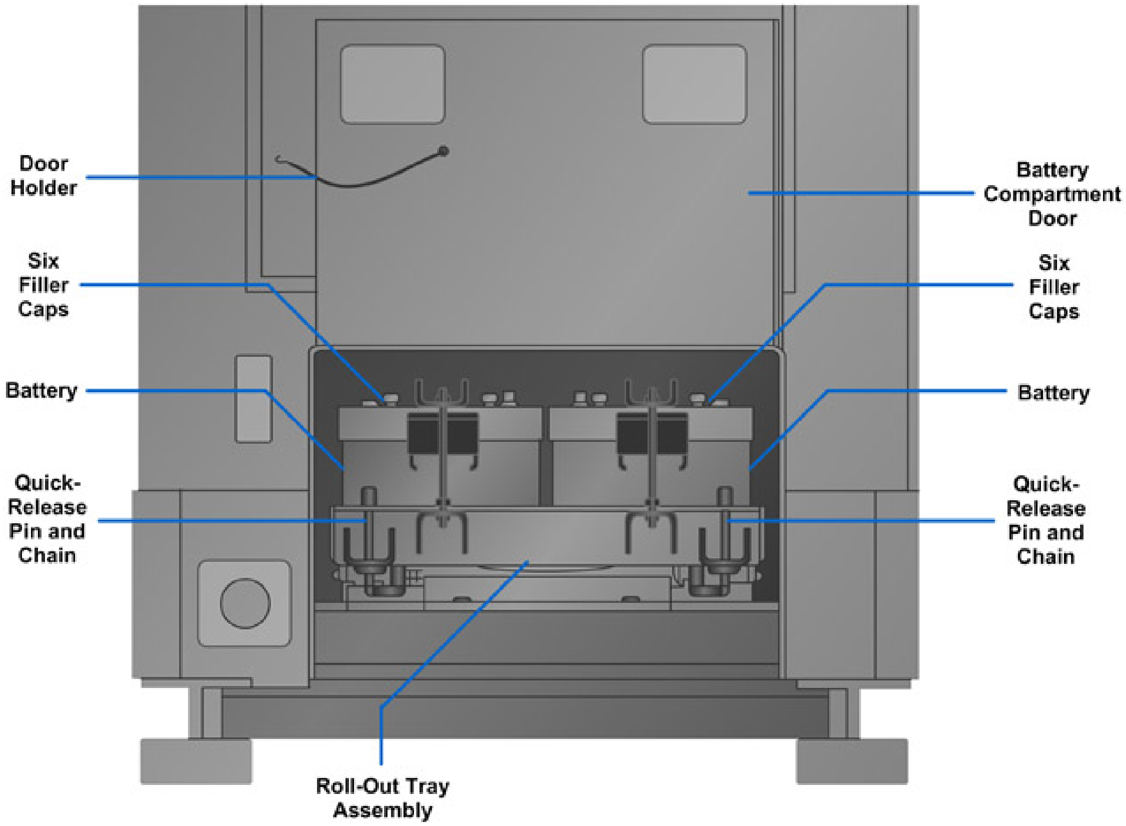

Figure 6-21 – Battery compartment.

1. Open the battery compartment door and secure it to the radiator grill with the door holder.
2. Depress the button on top of the quick-release pins, lift up the pins, and pull the roll-out tray assembly out.
3. Remove the filler caps. When you have electrolyte of the correct specific gravity, do not dilute it, but fill the battery cells to the cell slots.
4. Push in the roll out tray assembly and install the quick release pins (*Figure 6-21*).

When you prepare your own electrolyte, consult a mixing chart (Table 6-3). In this case, use the specific gravity value recommended in the instruction manual.

Table 6-3 — Electrolyte Mixing Chart

SPECIFIC GRAVITY DESIRED	USING 1.835 SPECIFIC GRAVITY ACID		USING 1.400 SPECIFIC GRAVITY ACID	
	PARTS OF WATER	PARTS OF ACID	PARTS OF WATER	PARTS OF ACID
1.400	3	22	-	-
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	5	3	4
1.225	11	3	1	1
1.200	13	3	13	10

WARNING

Be sure to add the acid to the water slowly, stirring constantly and thoroughly.

The temperature of the electrolyte when placed in the cells should be between 60°F and 90°F. IT SHOULD NEVER EXCEED 90°F.

A chemical reaction occurs when you add electrolyte to the battery, thereby causing the battery to heat. Cool it artificially (cooling fans) or allow it to stand at least 1 hour before placing it in service.

You will notice at the end of the cooling period that the level of the electrolyte has dropped because of the electrolyte soaking into the plates and separators. Before placing the battery in service, restore the electrolyte to its proper level. Remove any electrolyte spilled on the battery, using a cloth dampened with a solution of bicarbonate of soda and water.

Although you can place the battery in service 1 hour after filling it with electrolyte, do so only in an emergency. If at all possible, give the battery an initial light charge.

After the battery has been charged, connect the battery into the starting system of the prime mover, as shown in *Figure 6-20*. Always connect the negative cable last.

5.2.0 Battery Charging

The manufacturer’s manual may specify charging procedures for the type of battery you are to charge. If so, follow those procedures.

There are several types of battery charges, but you will generally use a normal charge, an equalizing charge, or a fast charge. We will discuss these three types of charges briefly. For more information on storage or dry-cell batteries and battery charging, refer to the *Navy Electricity and Electronics Training Series (NEETS)*, NAVEDTRA 172-01-00-88 (Module 1).

5.2.1 Normal Charge

A normal charge is a routine charge given according to the battery nameplate data during the ordinary cycle of operation to restore the battery to its charged condition.

5.2.2 Equalizing Charge

An equalizing charge is a special extended normal charge that is given periodically to batteries as part of a maintenance routine. It ensures that all the sulfate is driven from the plates and that all the cells are restored to a condition of maximum specific gravity. The equalizing charge is continued until the specific gravity of all cells, corrected for temperature, shows no change for a 4-hour period.

5.2.3 Fast Charge

A fast charge is used when a battery must be recharged in the shortest possible time. The charge starts at a much higher rate than is normally used for charging. It should be used only in an emergency, as this type of charge may be harmful to the battery.

5.2.4 Charging Rate

Normally, the charging rate of Navy storage batteries is given on the battery nameplate. If the available charging equipment does not have the desired charging rates, the nearest available rates should be used; however, the rate should never be so high that violent gassing occurs.

5.2.5 Charging Time

Continue the charge until the battery is fully charged. Take frequent readings of specific gravity during the charge and compare them with the reading taken before the battery was placed on charge.

5.2.6 Gassing

When a battery is being charged, a portion of the energy breaks down the water in the electrolyte. Hydrogen is released at the negative plates and oxygen at the positive plates. These gases bubble up through the electrolyte and collect in the air space at the top of the cell. If violent gassing occurs when the battery is first placed on charge, the charging rate is too high. If the rate is not too high, steady gassing develops as the charging proceeds, indicating that the battery is nearing a fully charged condition.

WARNING

A mixture of hydrogen and air can be dangerously explosive. No smoking, electric sparks, or open flames are permitted near charging batteries.

5.2.7 Charging Procedure

If the instruction manual for the generator set is not available or if it does not give the battery a charging procedure, proceed as follows: Connect the positive battery charger terminal to the positive battery terminal and the negative charger terminal to the negative battery terminal.

Charge the battery at a low rate (about 5 amperes) until the voltage and specific gravity, corrected to 80°F (27°C) remains constant for at least 4 hours. If the temperature of the electrolyte reaches 110°F (43°C), reduce the charging rate or stop the charge until the battery cools. NEVER PERMIT THE TEMPERATURE TO EXCEED 115°F (46°C). During the charging, replenish any water lost by evaporation.

5.3.0 Hydrometer

A hydrometer is the instrument used to measure the amount of active ingredients in the electrolyte of the battery (Refer to *Figure 6-22*). The hydrometer measures the SPECIFIC GRAVITY of the electrolyte. Specific gravity is the ratio of the weight of the electrolyte to the weight of the same volume of pure water, The active ingredient, such as sulfuric acid or potassium hydroxide, is heavier than water. Because the active ingredient is heavier than water, the more active the ingredient in the electrolyte, the heavier the electrolyte will be; the heavier the electrolyte, the higher the specific gravity.

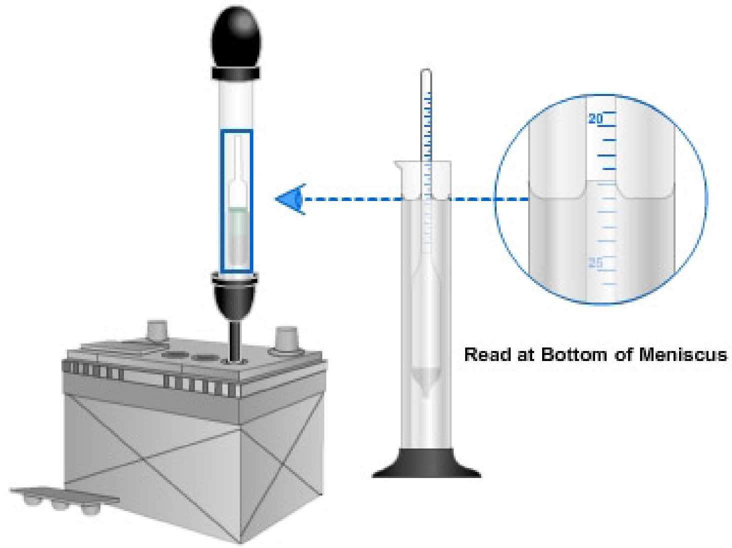

Figure 6-22 – Hydrometer.

A hydrometer is a glass syringe with a float inside it. The float is in a hollow glass tube, weighted at one end and sealed at both ends, with a scale calibrated in specific gravity marked on the side. The electrolyte to be tested is drawn into the hydrometer by the suction bulb. Enough electrolytes should be drawn into the hydrometer so that the float will rise. Hydrometers should not be filled to the extent that the float rises into the suction bulb. Since the weight of the float is at its base, the float will rise to a point determined by the weight of the electrolyte. If the electrolyte contains a large concentration of the active ingredient, the float will rise higher than if the electrolyte has a small concentration of the active ingredient.

To read the hydrometer, hold it in a vertical position and take the reading at the level of the electrolyte. Refer to the manufacturer's technical manual for battery specifications to find the correct specific gravity ranges. An example of what your manual may say about the specific gravity is that for a fully charged battery the specific gravity should be 1.280 ± 0.005. The manual may tell you to recharge the battery if the specific gravity is less than 1.250.

Always return the electrolyte in the hydrometer to the cell of the battery from which it was taken.

NOTE

Flush hydrometers with fresh water after each use to prevent inaccurate readings. Do *not* use storage battery hydrometers for any other purpose.

Perhaps it should be said that adding the active ingredient (sulfuric acid, for example) to the electrolyte of a discharged battery does not recharge the battery. Adding the active ingredient only increases the specific gravity of the electrolyte and does not convert the plates back to active material, and so does not bring the battery back to a charged condition. A charging current must be passed through the battery to recharge it.

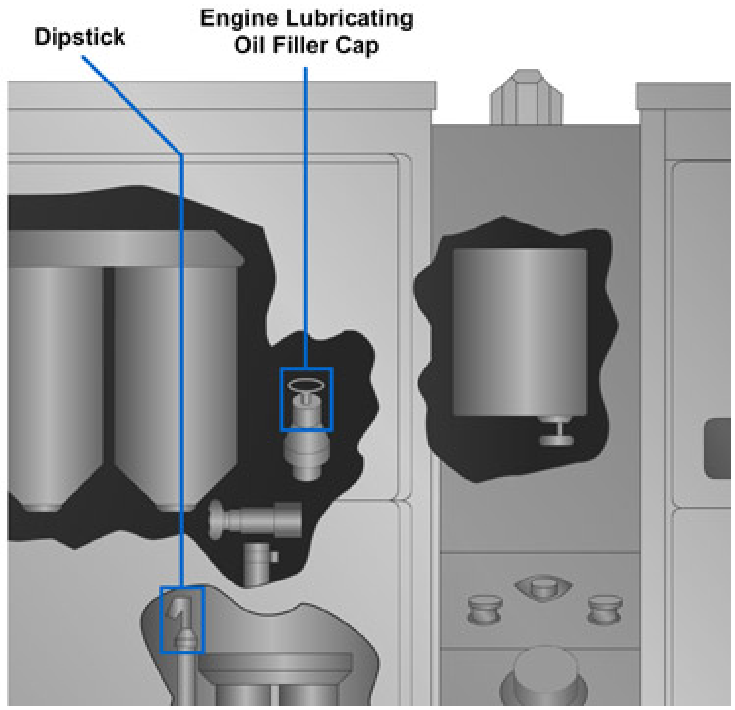

Figure 6-23 – Oil cap and dipstick locations.

5.4.0 Oil

You must check the engine crankcase oil level before operating the generator set. The engine dipstick (*Figure 6-23*) is the crankcase oil level gauge. The dipstick in the generator engine is the shielded type, which allows checking the oil level while the engine is either stopped or running. The dipstick is stamped on both sides to indicate the two different oil levels. The engine running side is stamped as follows: "ADD," "FULL," and "RUNNING." The engine stopped side is stamped as follows: "ADD," "FULL," and "STOPPED." Be sure to use the appropriate add and full marks, depending on whether the engine is stopped or running. Also, ensure that the appropriate side of the dipstick is up when inserting it since the underside will be wiped in the gauge tube when the dipstick is removed, therefore indicating a false oil level reading.

To check the oil level, first remove and wipe the oil from the dipstick. Loosen and remove the oil filler cap (*Figure 6-23*) to allow the pressure to escape. Reinsert the dipstick (with the appropriate side up) and remove it to observe the oil level. Add oil through the fill tube, as required, to obtain the "full" level on the dipstick. Be sure to use the proper grade of oil. A lubricant chart in the instruction manual furnished with each generator will show the proper grade of oil to use at the operating temperature.

5.5.0 Water

Check that the level of coolant is within 2 inches (51 mm) of the top of the radiator.

WARNING

Do not attempt to remove the radiator cap until the radiator has cooled to a point where there will be no built-up steam pressure. Failure to observe this warning could result in second- or third-degree bums.

Using an antifreeze solution tester, (*See Figure 6-24*) check that the antifreeze content is sufficient for the existing ambient temperature. Add antifreeze as required.

Whenever you fill the radiator with coolant after it has been drained, fasten a tag near the radiator cap. The tag should indicate the type of coolant and the degree of protection the coolant gives.

Regardless of the air temperature, be sure to use an antifreeze solution in the proportions recommended in the instruction manual for the generator.

Figure 6-24 – Antifreeze solution tester.

5.6.0 Fuel

The fuel tank should be filled with clean fuel oil, strained if necessary. Service the fuel tank as follows:

WARNING

Always maintain constant metal to metal contact between the fuel tank filler neck and the spout of the fuel supply. That will prevent the possibility of sparking caused by static electricity.

Remove the fuel tank filler cap (*Figure 6-25*), and fill the fuel tank with the proper fuel. (Refer to the instruction manual.) Replace the filler cap and wipe up any spilled fuel.

Remove the cap from the fuel tank drain valve and open the valve. Let water and sediment drain into an approved nonflammable container. When clean fuel runs out of the tank, close the drain valve and install the cap on the valve.

A day tank is one of the major components of the fuel system. It has a capacity to permit engine operation for a minimum of 5 minutes. The day tank also provides a settling point for contaminants (to prevent their entry into the engine) and supplies fuel to the engine fuel pump.

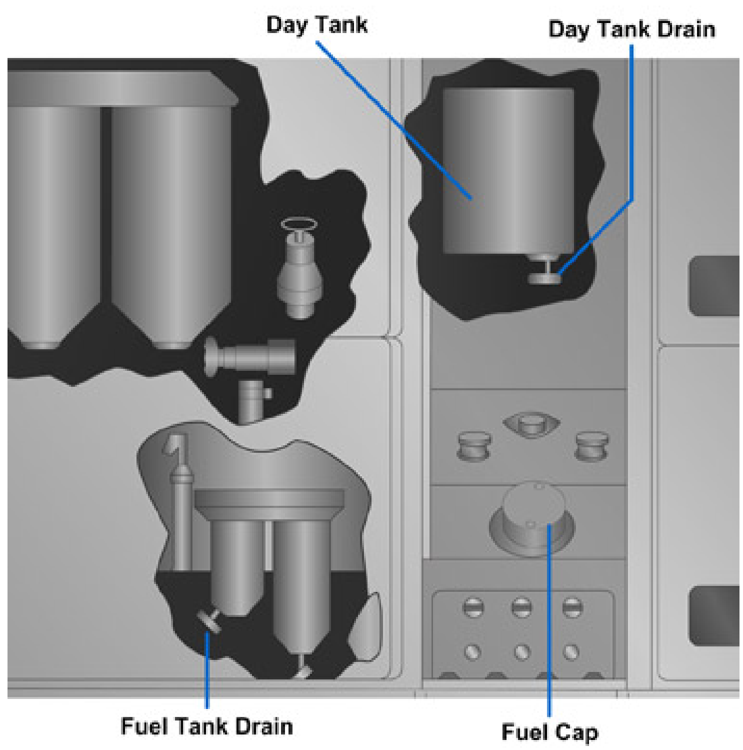

Figure 6-25 – Fuel system component locations.

The day tank contains a dual type of float switch. The upper float operates in conjunction with the fuel solenoid valve to maintain a predetermined fuel level in the tank. The lower float initiates an engine shut-down sequence. This sequence is initiated in the event that the fuel level in the tank will permit operation of the generator set at the rated load for only 1 minute.

You must drain sediment and water from the day tank as you did from the fuel tank. Remove the cap from the day tank drain valve and open the valve. (Refer to *Figure 6-25*) for the location of the tank and its drain valve.) Drain water and sediment into a container. Close the valve when clean fuel runs out of the tank, and install the cap back on the valve.

5.7.0 Ventilation

WARNING

Do not operate the generator set in an enclosed area unless the exhaust gases are piped to the outside. Inhalation of exhaust gases will result in serious injury or death.

Keep the area around an operating generator set well ventilated at all times so that the generator set will receive a maximum supply of air.

Consider ventilation when you install the units inside a building. Every internal combustion engine is a HEAT engine. Although heat does the work, excess amounts of it must be removed if the engine is to function properly. This can be accomplished by setting the radiator grill of the engine near an opening in the wall and providing another opening directly opposite the unit. In this manner, cool air can be drawn in and the hot air directed in a straight line outdoors. These openings can be shielded with adjustable louvers to prevent the entrance of rain or snow. In addition, when the generator is operating in extremely cold weather, the temperature in the room can be controlled by simply closing a portion of the discharge opening. Additional doors or windows should be provided in the shelter if the plants are installed in localities where the summer temperatures exceed 80°F at any time.

5.8.0 Exhaust System

The muffler and the exhaust pipe are connected to the turbocharger exhaust elbow (*Figure 6-26*) and provide a path for engine exhaust gases to exit the generator set. The muffler reduces the noise level of the engine exhaust. The discharge opening of the muffler is covered by a hinged cap to prevent water from entering the exhaust system when the generator is not operating.

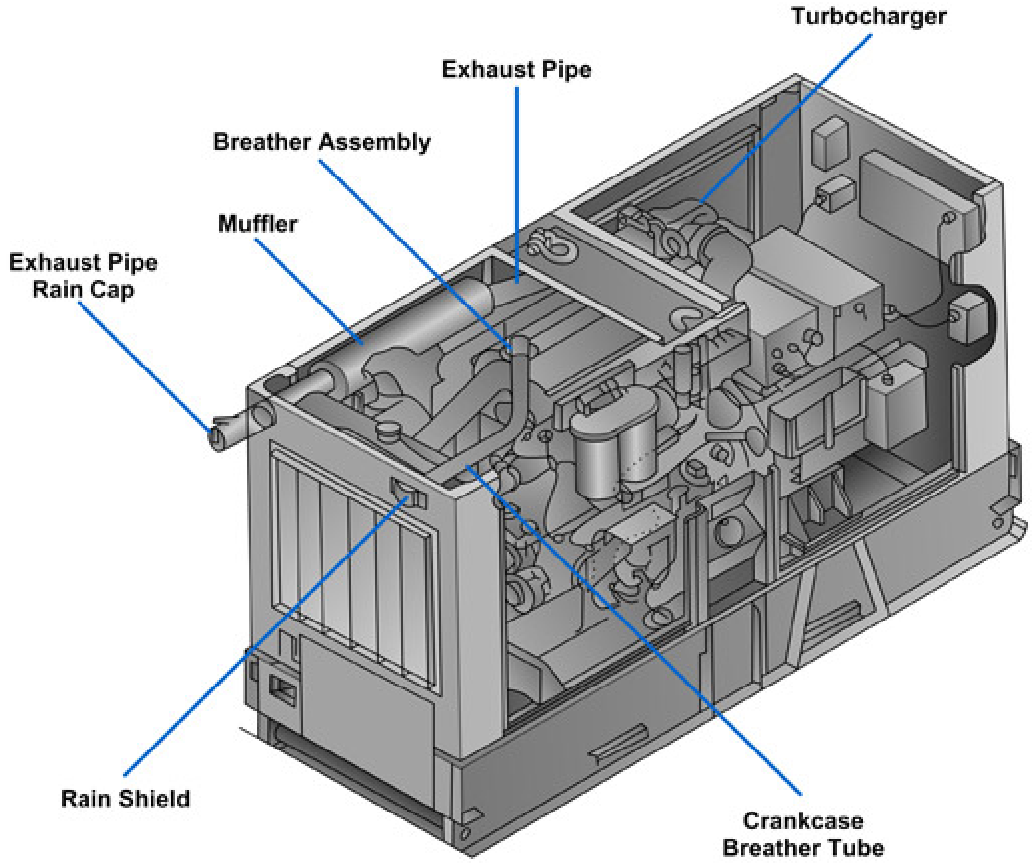

Figure 6-26 – Generator exhaust and breather system.

Let's look at an example of an indoor installation. After bolting the generator set to the concrete pad and enclosing it in a shelter, you are about to vent the exhaust system to the outside. You lift the exhaust cap and connect the gastight exhaust pipe to the discharge opening. You then extend the pipe through the wall (or roof) of the building in a route that includes no obstructions and a minimum number of bends. If you have arranged the pipe to slope away from the engine, condensation will not drain back into the cylinders. If the exhaust pipe has to be installed so that loops or traps are necessary, place a drain cock at the lowest point of the system. All joints must be perfectly tight; and where the exhaust pipe passes through the wall, you must take care to prevent the discharged gas from returning along the outside of the pipe back into the building. Exhaust piping inside the building must be covered with insulation capable of withstanding a temperature of 1500°F.

The crankcase breather tube is clamped to the engine breather assembly. The breather tube provides a path for engine crankcase vapors to exit the generator set. A rain shield is provided at the tube outlet to prevent rain from entering the tube when the generator is used outdoors.

5.9.0 Phase Sequence Indicators

The phase sequence indicator is a device used to compare the phase sequence of three-phase generators or motors. Examples of its use are as follows: to compare the phase rotation of an incoming alternator that is to be operated in parallel with an alternator already on the line or to determine the phase rotation of motors being put into use for the first time.

One type of phase sequence indicator is a tiny three phase induction motor. The three leads of the motor are labeled "A," "B," and "C," as shown in *Figure 6-27*. The insulating hoods over the clips are of different colors: red for A, white for B, and blue for C.

The rotor in the instrument can be observed through the three ports as it turns so that you can note the direction in which it rotates. You can start the rotor by means of a momentary contact switch: it stops again when you release the switch.

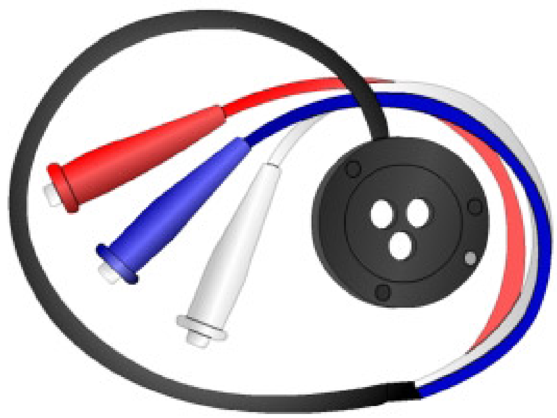

Figure 6-27 – Phase sequence indicator.

You also may use a solid-state phase sequence indicator with two lights. Whichever light is on indicates the phase sequence of the voltage in the conductors to which the instrument is connected; for example, the light labeled "ABC" indicates one phase sequence, while the other light, labeled "BAC," indicates another. If you are working with three-phase conductors (all of the same color) that are installed but not labeled, you may connect the phase sequence indicator to the three conductors, turn on the power, check the phase sequence of the conductors as connected to the instrument, and turn off the power. You may then label the conductors with numbers, letters, or colored marking tape.

You also may check the phase sequence of an incoming alternator before paralleling it with an operating load-side alternator. Connections must be made so that the phase sequence of the two generators will be the same.

Figure 6-28 shows the leads of two generators to be parallel. The proper procedure for ensuring phase sequence with a phase sequence indicator is as follows: Connect indicator terminals A to X_1, B to Y_l, and C to Z_1, press the contact switch, and note the direction of rotation of the rotor.

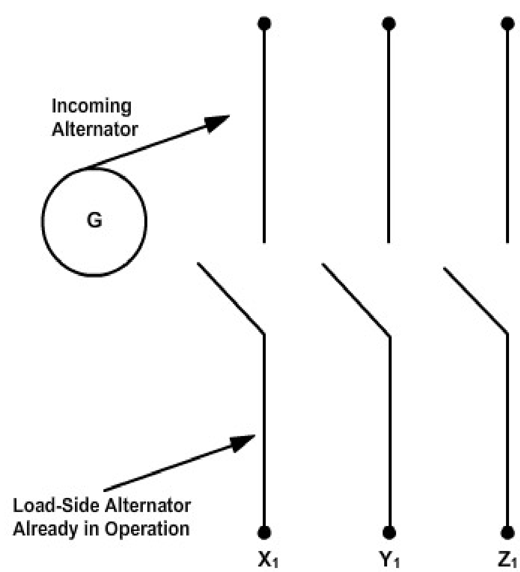

Figure 6-28 – Diagram for checking phase sequence of alternators.

Now move the A terminal to X, the B to Y, and the C to Z, and again press the switch. If the rotor turns in the same direction as before, the phase rotation is the same for the alternators, and the connection can be made X to X_1, Y to Y_1, and Z to Z_1. If the rotor turns in the opposite direction, transpose the connections of any two of the incoming alternator leads before making the connection.

It is not absolutely necessary that A be connected to the left-hand terminal, B to the center terminal, and C to the right-hand terminal. This is a practical method, however, used to avoid the danger of confusing the leads. The important thing is to ensure that the phase sequence indicator that was used on X_1 be brought down to X, the one used on Y_1 to Y, and the one used on Z_1 to Z. Reversing any two of the leads will reverse the direction of rotation of the rotor of the instrument.

6.0.0 DISTRIBUTION PANELBOARDS

Power from the generator set must be delivered to various connected loads safely and efficiently. The relatively large cables connected to the load terminal board of the generator, if sized properly, can conduct all the power the generator can produce. This power has to get to the different connected load equipment without overloading the conductors or overheating conductor insulations.

This section presents the makeup of panelboards, connections to them, and the installation of the advanced-base type of portable panelboards.

6.1.0 Overcurrent Protection

If the load cables come in contact with each other and short-circuit the generator, the generator windings could be damaged by excessive current unless the generator windings and load cables are protected by a circuit breaker. The circuit breaker "breaks" or interrupts the circuit anytime there is a short circuit or overload condition in the load cables.

One large load, consuming an amount of power at or near the maximum power output of the generator, could theoretically overload the generator in the event of a fault. In this case, one circuit breaker could trip the circuit and protect both the generator and the load. But small-load conductors connected directly to the larger generator load cables could likely burn up without drawing enough current to cause the circuit breaker of the generator set to open the circuit.

In the interest of safe operation of load circuit conductors and safety of area personnel, you must use properly sized overcurrent devices (circuit breakers or fuses).

6.2.0 Distribution

The generator load cables are terminated at a type of distribution bus bar from which one or more overcurrent protective devices are connected. Current through each of the overcurrent devices is limited by the overcurrent rating or setting of the device. In this way power from the generator may be safely distributed through protected conductors to the various connected loads.

6.3.0 Panelboards

A panelboard includes buses and automatic overcurrent protective devices placed in a cabinet or cutout box and mounted in (flush) or against (surface) a wall or partition. The panelboard is accessible only from the front. A panelboard serves the purpose mentioned above for the distribution of electric power (*Figure 6-29*).

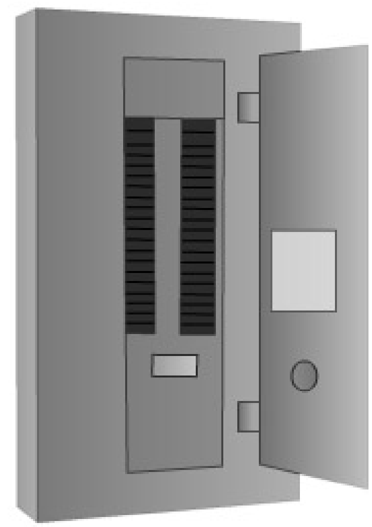

Figure 6-29 – Panelboard

6.3.1 Phase Relationship

When you connect the generator load to the panelboard, be careful to match the cable markings to the panelboard terminals. Maintain the same phase relationship throughout the wiring system from the generator to the load. You may see terminals marked with numbers, such as L1, L2, L3, and L0 (*Figure 6-30*, View A) or the letters and symbols A0, B0, C0, and N (*Figure 6-30*, View B). Wire in different parts of the system may be marked with numbered, lettered, or colored tape. (The color sequence is black, red, blue, and white.) Either way, the phase sequence is the same.

You may have to "ring out" (identify) unmarked cables or conductors in the conduit (*Figure 6-30*, View C) before connecting them to the power source or load. This identification process can be accomplished in any one of several ways. You may use a bell and battery, buzzer and battery, or ohmmeter, for example. Any of these devices may be used to check for continuity through each conductor to ground (a conduit, for example). After a conductor is identified, it is then marked.

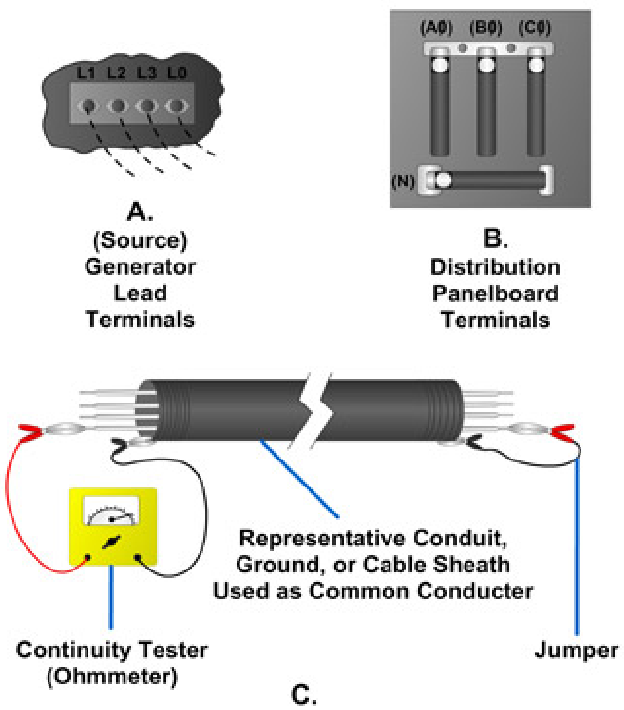

Figure 6-30 – Conductor identification.

6.4.0 Portable Power Distribution Panelboards

Portable, weatherproof power distribution panelboards are available, similar to the one shown in *Figure 6-31*. Load cables can be plugged into the receptacles along the front (*Figure 6-31*, View A). With the cover raised (*Figure 6-31*, View B), they provide access to the circuit breakers and test jacks. This panelboard is an advanced-base distribution center. A single-line diagram of the bus and circuit breakers is shown in *Figure 6-32*.

Portable generators and panelboards can be placed into service quickly and with relatively little effort compared to a permanent installation. Do not let expedience cause you to become careless, though, in placing the equipment and routing the load cables. Careful planning can result in much safer and more efficient installation for both you and your fellow Seabees.

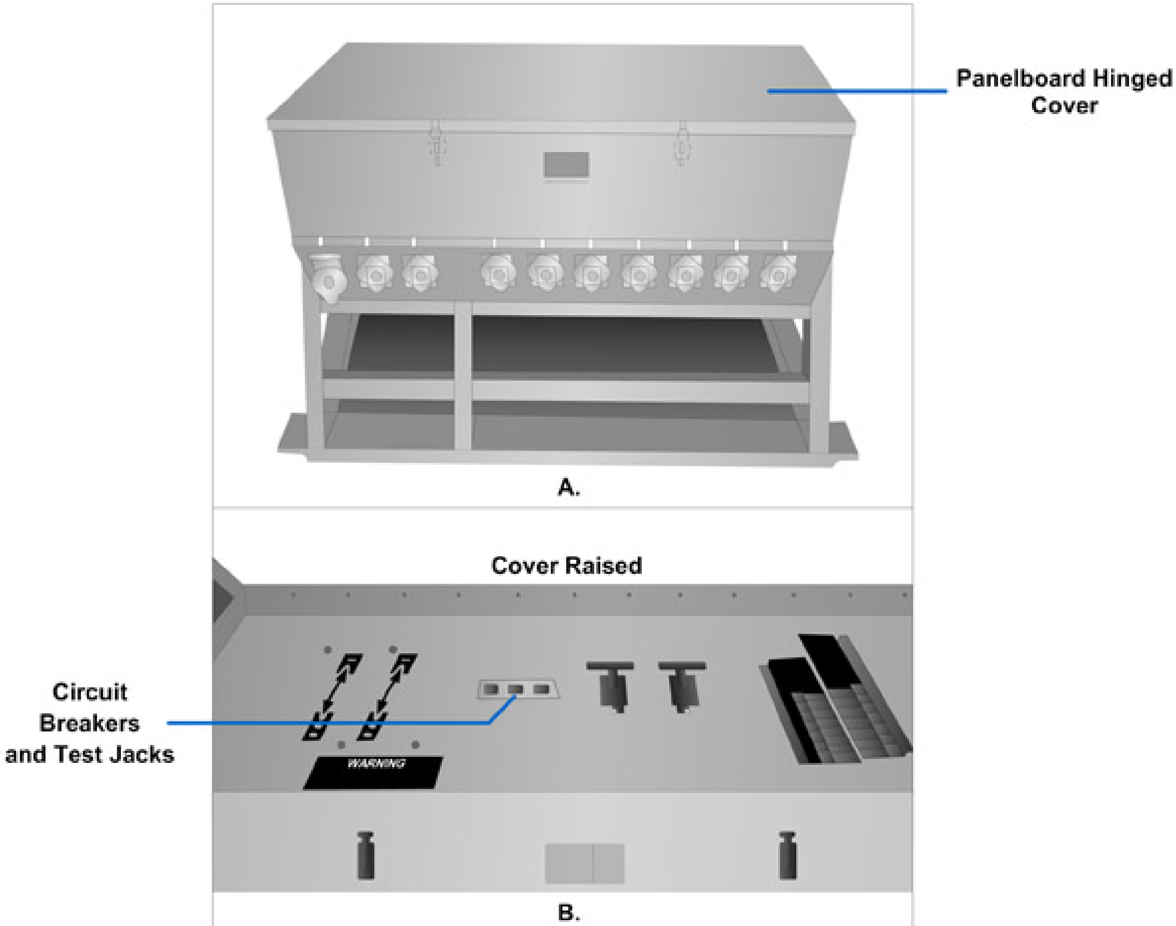

Figure 6-31 – Portable power distribution panelboard.

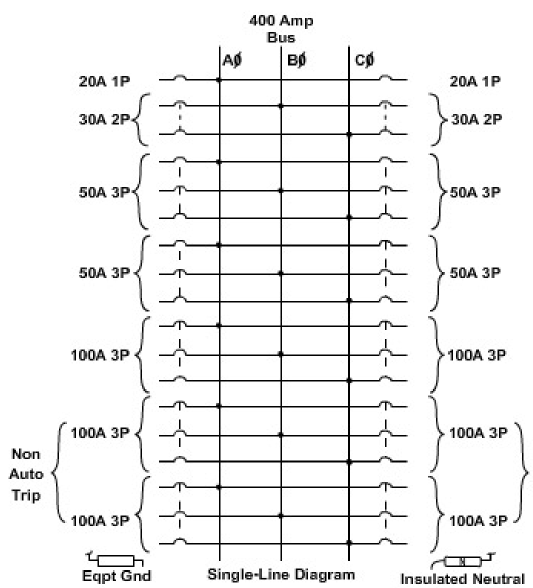

Figure 6-32 – Diagram of the portable power distribution panelboard.

Test your Knowledge (Select the Correct Response)

2. What effect does short circuited load cables have on the generator windings?

   A. Nothing
   B. Damaged by excessive current
   C. Greater output achieved
   D. Damaged by phase imbalance

7.0.0 POWER PLANT MAINTENANCE

There are actually three major categories (or levels) of maintenance. The three categories are (1) depot, (2) intermediate, and (3) organizational. In depot or intermediate maintenance, equipment is restored to like-new condition or subjected, to some degree, to detailed repairs. Under the organizational category, generator maintenance may consist of inspection, testing, adjustment, and so forth, and then perhaps replacement of, rather than repair of, a faulty component.

Two types of organizational maintenance are (1) operator and (2) preventive. Each of the two types should complement the other.

Defects discovered during operation of the unit will be noted for future correction either by the operator or by maintenance personnel, as appropriate. The purpose of preventive maintenance is to keep the machinery running trouble-free. The operator will likely have fewer problems if the preventive maintenance work is done well.

In our previous discussion we have seen that operator maintenance includes many of the tasks you do before, during, and after you operate the generator set to produce power.

As a member of a unit or organization large enough to have a maintenance crew, you may serve as a member of the crew. As a crew member, you will perform organizational preventive maintenance functions on the generator set periodically according to the manufacture's specifications or to service maintenance manuals.

To prevent buildup of contaminants that may cause damage to the operating components or systems of the generator set, clean the set periodically. Cleaning operations must be performed only on generator sets that are not operating, that are connected to a parallel bus, or that are connected in a standby mode. To clean the generator set, heed the warnings and cautions given, and proceed as follows:

WARNING

Compressed air used for cleaning can create airborne particles that may enter the eyes. Pressure shall not exceed 30 psig. Wearing of goggles is required.

CAUTION

Exercise care to prevent dry-cleaning solvent from coming into contact with electrical components.

Wipe painted metal surfaces with a clean lint-free cloth moistened with cleaning solvent (P-D- 680, type II). Scrub off hard deposits with a bristle brush that has been dipped in solvent. Dry the surfaces with a clean lint-free cloth.

WARNING

Dry-cleaning solvent, P-D-680, type II, is flammable and moderately toxic to the skin and eyes. Respiratory and eye protection are required.

Remove any dust, dirt, or sand from inside the generator set with a damp, lint-free cloth.

Disconnect the battery cables (negative cable first) and remove any corrosion from the battery terminals, cables, and hold-down with a wire brush. Clean the battery filler cap vent holes.

Clean the instrument faces with a clean, lint-free cloth.

Inspection and servicing procedures covered in this chapter are rather general. In most cases, they can be applied to any electrical power generator that you install. You realize, of course, that there are other special installation details that pertain only to the particular generator you happen to be working on. Because of the many different types of generators, certain instructions are applicable only to specific types of generators; therefore, you should consult the manufacturer's instruction manuals for these details.

Power plant maintenance can be divided into two general categories: operator maintenance and preventive maintenance.

7.1.0 Operator Maintenance

Operator maintenance includes the hourly, daily, and weekly maintenance requirements recommended in the manufacturer's literature. Some operator maintenance and routine checks include the following:

- Bring oil level to the high mark on the dip stick.
- Free movement of ventilation louvers.
- Drain water and sediment from strainers and filters.
- Maintain level of coolant.
- Check radiator and coolant hoses for leaks.
- Check battery electrolyte level.
- Check all switches for proper operation.
- Drain water from fuel tank.
- Fill fuel tank as required with appropriate diesel fuel.
- Check fuel tank for leaks.

Log all operator maintenance in the operations log book when it is completed.

7.2.0 Preventive Maintenance

Preventive maintenance includes the monthly, quarterly, semiannual, and annual maintenance checks recommended in the manufacturer's literature. The maintenance supervisor is responsible for establishing a maintenance schedule to ensure the preventive maintenance is performed. A maintenance log book should be established for each generator plant and all maintenance checks recorded. The operation log book should be reviewed periodically by watchstander and supervisor to ensure that all preventive maintenance recommended by engine operating hours is scheduled; for example, the schedule of engine lube oil and filter replacement is normally based on hours of operation.

8.0.0 TQG-B GENERATOR

8.1.0 Generator Characteristics, Components and Instrumentation

This section is about the components that make up the Tactical Quiet Generator – Bravo (TQG-B) (Refer to *Figure 6-33*). Failing to understand the components of the TQG-B could lead to personnel injury or death and damage to the generator. You will also learn about the characteristics of the TQG-B and the differences between it and the previous TQG-A model. Also included is the description of components and instrumentation of the TQG-B.

Figure 6-33 – TQG-B Generator.

Before learning about the components of the TQG-B, take a moment to read the next two important safety warnings (Refer to *Figure 6-34*). It is imperative for you to take each warning seriously. Remember to make sure the unit is completely shut down and free of any power source before attempting any repair or maintenance on the unit. High voltage is produced when the generator set is in operation and failure to comply can result in injury or death to personnel. It is imperative for you to take this warning seriously. Remember to remove metal jewelry when working on electrical system or components. Metal jewelry can conduct electricity and failure to comply can cause injury or death to personnel by electrocution.

Figure 6-34 – Warning notices.

8.1.1 Differences between TQG-A and TQG-B

The TQG-Bravo recently took the place of the Alpha model, but many Alphas are still in service (Refer to *Figure 6-35* and *Figure 6-36*). Here you see some similarities between the Alpha and Bravo models. Both models deliver the same precise power with the same voltage and frequency. Both generators also have the same engines: John Deere Diesel/JP-8 engines.

Similarities between both models:

- Both models deliver the same precise power, voltage, and frequency levels.
- Both have the same engines.
- Output: 30,000 Kw
- Voltage: 120/208 low wye
  240/416 high wye
- Frequency: 50 – 60 Hz
- Engine: John Deere JP-8 Diesel

Figure 6-35 – TQG-A.

While the TQG-A and the TQG-B do have some similarities, they also have some important differences that you need to be aware of. The differences are: The Bravo model has a Digital Control System or DCS. And the Alpha model uses physical gauges, lights and meters. It is important to know that you cannot parallel a TQG-Alpha with a TQG-Bravo. Attempting to do so will result in damage to the generator sets.

Figure 6-36 – TQG-B.

8.2.0 Components and Instrumentation of the TQG-B

The TQG-Bravo models have several components and instruments with which you need to be familiar. You will learn about the components and instruments in a 360° rotation starting at the rear and completing on the right side of the generator.

Refer to *Figure 6-37* when discussing rear portion of TQG-B.

8.2.1 Rear: Components and Instruments

8.2.1.1 DCS

Here you see the DCS that you will use to start, operate, and shut down the TQG-B. It is extremely important that you know the function of each component and instrument on the DCS.

Figure 6-37 – TQG-B Rear components.

8.2.1.2 Air Cleaner Assembly

The air cleaner assembly is located on the front, behind the air cleaner access door. The air cleaner assembly has a dry-type, disposable paper filter and canister. There is also a restriction indicator, which will pop up during operation when the air cleaner requires servicing.

8.2.1.3 Paralleling Receptacle

The paralleling receptacle is used to connect the paralleling cable between two generator sets of the same size and model to operate in parallel.

8.2.1.4 Convenience Receptacle

The convenience receptacle is a 120 VAC receptacle used to operate small plug-in type equipment. This can be used to operate a laptop and other normal appliances.

8.2.1.5 Ground Fault Circuit Interrupter Test Switch

The ground fault circuit interrupter consists of the test switch and reset switches. The test switch tests to see if the ground fault circuit interrupter is working. The reset switch resets the ground fault circuit interrupter.

8.2.2 Left Side Components and Instrumentation

Refer to *Figure 6-38* when discussing left side portion of TQG-B.

8.2.2.1 Radiator

The radiator is in the front of the engine compartment. It acts as a heat exchanger for the engine coolant and helps keep the engine cool.

8.2.2.2 Dead Crank Switch

The dead crank switch is located on the left side of the engine compartment. The switch allows for engine turn-over without starting for maintenance purposes.

8.2.2.3 Dipstick

The dipstick is on the left side of the engine compartment. The dipstick measures the oil level in the engine drain pan. It has two sides, an engine stopped or cold side and an engine running or hot side.

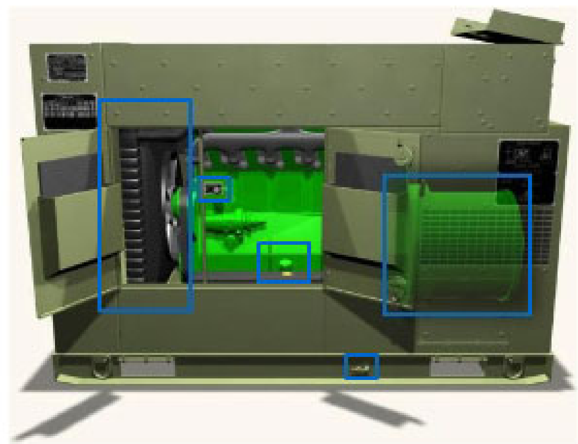

Figure 6-38 – Left side components of the TQG-B generator.

8.2.2.4 Fuel Drain Valve

The fuel drain valve is on the left side of the generator set's skid base. The fuel drain allows fuel to be drained for maintenance.

8.2.2.5 AC Generator

The AC generator is coupled directly to the rear of the diesel engine and is the component that produces electricity using the energy from the diesel engine.

8.2.2.6 Actuator

The actuator is on the engine's left side. The actuator regulates fuel amounts that enter the engine to maintain the desired engine speed.

8.2.2.7 Turbocharger

The engine's turbocharger takes air from the intake filter. Exhaust gases are pushed into the turbine of the turbocharger through the exhaust manifold. The turbine drives the turbocharger, which compresses the intake air and forces it into the engine, creating more powerful explosions in the combustion chambers.

8.2.2.8 Fuel Pump

The fuel pump is on the engine's left side. It delivers fuel to the Fuel Injection Pump.

8.2.2.9 Magnetic Pickup

The magnetic pickup is on the rear bell housing of the engine's flywheel. It uses magnetic impulses to monitor engine speed for the governor control unit.

8.2.3 Front End Components and Instrumentation

Refer to *Figure 6-39* when discussing front end portion of TQG-B.

8.2.3.1 Batteries

Two maintenance free 12-volt DC batteries are located at the front of the TQG-B. The generator is capable of operating without the batteries connected after it is started. There is a diode behind the control panel that protects the generator set if the batteries are connected incorrectly.

Figure 6-39 – Front end components of the TQG-B generator.

8.2.3.2 Oil Drain Off Valve

The oil drain valve is located at the front of the generator. This is where oil is drained for maintenance purposes.

8.2.4 Right Side Components and Instrumentation

8.2.4.1 NATO Slave Receptacle

The NATO slave receptacle is located on the right side of the generator set. The NATO receptacle is used for remote battery operation and jump starting the unit from any another piece of equipment that has a 24 VDC starting system.

8.2.4.2 Load Output Terminal

The load output terminal board is at the rear of the generator on the right side. It consists of four AC output terminals mounted on a board. The four terminals are labeled L1, L2, L3 and L0. There is also a fifth terminal labeled GND that serves as the ground for equipment. A copper bar is connected between the L0 and GND terminals. (*Figure 6-40*)

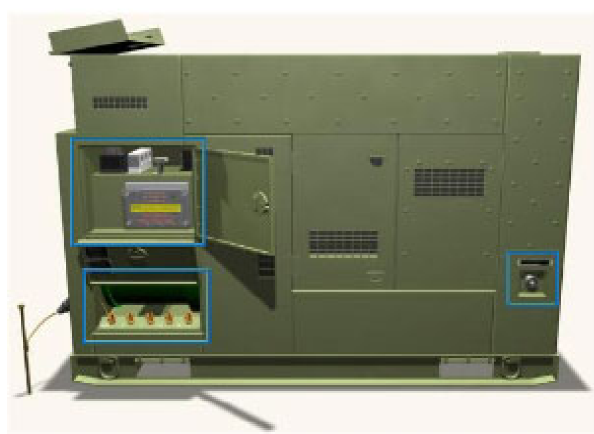

Figure 6-40 – Right side components of TQG-B generator.

8.2.4.3 Reconnection Board

The reconnection board is located on the right side of the generator at the rear above the Load Output Box. The reconnection board allows reconfiguration from 120 to

208 for low wye and 240 to 416 for high wye VAC output.

8.2.4.4 Muffler

The muffler and exhaust tubing are connected to the engine's turbo charger. The exhaust exits through the top of the generator set. Gases are exhausted upward.

8.2.4.5 Radiator Fill Bottle

The radiator fill bottle is located on the right side of the engine. The bottle has hot and cold markings that indicate where the coolant levels should be during operation when hot and when cold. Only authorized personnel can add coolant to the engine and only through the fill bottle.

8.2.4.6 Serpentine Fan Belt

The serpentine fan belt is located in the engine compartment on the front of the engine. The fan belt drives several components including the fan, water pump, and battery-charging alternator.

8.2.4.7 Water Pump

The water pump is located at the front of the engine. The pump circulates coolant through the engine block and the radiator.

8.2.4.8 Battery Charging Alternator

The battery-charging alternator is located on the right side of the engine. It is capable of constantly charging the batteries to keep them in a charged state in addition to providing the required 24 Volts to the control circuits. The alternator is protected by an inline fuse rated at 30 amps located above the fuel tank and below the alternator.

8.2.4.9 Oil Filter

The oil filter is in the engine compartment on the left side. The oil filter removes impurities from the oil.

8.2.4.10 Starter

The starter is on the right side of the engine. The starter motor engages the engine's flywheel to start the diesel engine.

8.2.4.11 Crankcase Breather Filter Assembly

The crankcase breather filter assembly is at the right side of the engine compartment. The filter element removes particles from oil and air contaminants when they pass from the crankcase to the engine air intake.

8.2.4.12 Fuel Filter/Water Separator

The fuel filter/water separator is on the right side of the engine compartment. The element removes water impurities from the diesel fuel.

8.3.0 Operation of TQG-B

8.3.1 Checklists for the TQG-B

Checklists exist to give you a thorough reference for inspecting the generator set at various points. The checklists contain a list of components for each of the sides of the generator set that need to be checked. There are four checklists for the before operations check, during operations check, after operations check and parallel operations. See *Figure 6-41*.

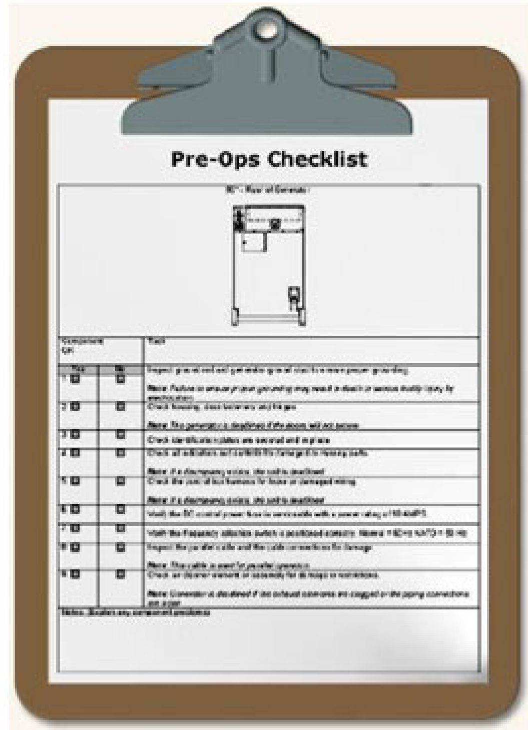

Figure 6-41 – Checklists utilized for TQG-B operation.

8.3.1.1 Before Operations Check

It is very important to check the components and instruments of the TQG-B before starting it. Performing the before operations check will ensure that the generator is in good condition to start. The generator set could be damaged or fail to start if the before operations check is not done or done incorrectly.

The checklist (refer to *Figure 6-42*) gives guidance for a thorough before operation exam of the generator. The Pre-Operations Checklist covers all the major components and instruments of the generator and is important because it:

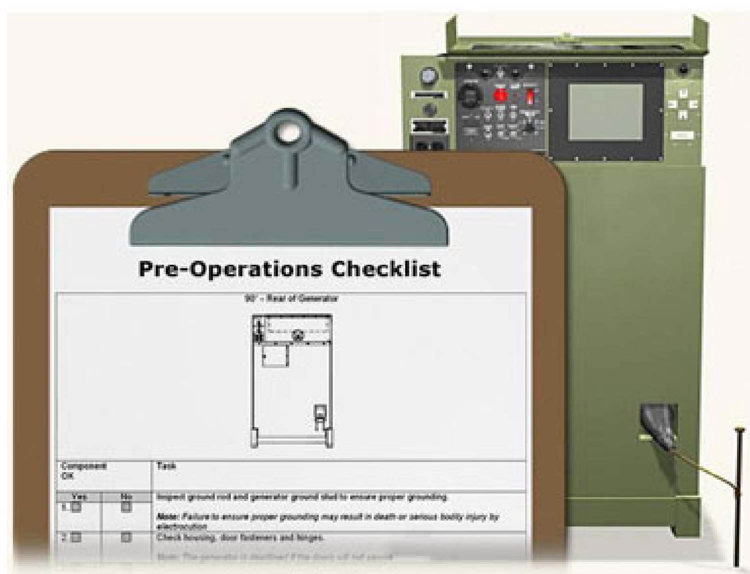

Figure 6-42 – Pre-Operational Checklist.

- Reduces the likelihood of damage to the generator
- Allows you to identify maintenance issues before they become a problem

- Increases the chances of supplying power to those crews that need it when they need it

Remember, never attempt to start the generator set unless it is properly grounded. The generator set produces high voltage when it is in operation and failure to comply can result in injury or death to personnel.

8.3.2 Before Operations Check: Rear

We will now use the pre-operations checklist to perform the before operations check. The before operations check is performed in a 360° rotation that starts at the rear of the generator. Refer to *Figure 6-43*.

8.3.2.1 Inspect Ground Rod

First inspect the ground rod and generator ground stud to ensure proper grounding. Remember that failure to ensure proper grounding may result in death or serious bodily injury by electrocution.

8.3.2.2 Housing Inspection

Check the housing, door fasteners, and hinges. Note that the generator will be deadlined if the doors are not secure.

8.3.2.3 Identification Plate Inspection

Check that the identification plates are secured and in place.

8.3.2.4 Indicator and Controls Inspections

Check all indicators and controls for damaged or missing parts. Note that if a discrepancy exists, the unit is deadlined.

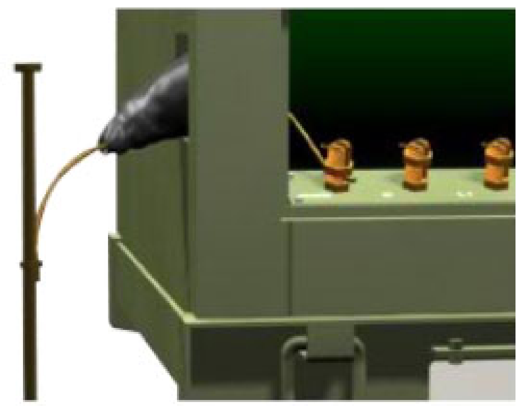

Figure 6-43 – Before operations check – rear.

8.3.2.5 Control Box Harness Inspection

Check the Control Box harness for loose or damaged wiring. Note that if a discrepancy exists, the unit is deadlined.

8.3.2.6 Power Fuse Inspection

Confirm that the DC power control fuse is intact and has a ten amp power rating.

8.3.2.7 Frequency Selection

Verify that the Frequency Selection Switch is at the correct position for the power you are providing. For NORMAL the switch should be set to NORMAL sixty hertz. For NATO the switch should be set to NATO 50 hertz.

8.3.2.8 Cable Inspections

Check the Parallel Receptacle and Parallel Cable for damage.

8.3.2.9 Air Cleaner Element Inspection

Inspect the air cleaner element and assembly for restrictions or damage. The Restriction Indicator will tell you whether the air cleaner filter needs changing.

8.3.3 Before Operations Check: Left Side

Refer to *Figure 6-44* for inspection points associated with before operations check – Left side.

8.3.3.1 Skid Base Inspection

Inspect the Skid Base for corrosion and cracks.

Figure 6-44 – Before operations check – Left Side.

8.3.3.2 Housing Inspection

Inspect the Engine Compartment housing, along with the Air Ducts and Exhaust Grills. You also need to check the door fasteners and hinges just like you did for the rear of the generator.

8.3.3.3 Identification Plate Inspection

Check that the Identification Plates are secured and in place.

8.3.3.4 Engine Compartment Inspection

Inspect the Engine Compartment for damage.

8.3.3.5 Engine Compartment Wiring Inspection

Inspect the Engine Compartment and look for loose or missing components.

8.3.3.6 Acoustic Material Inspection

Inspect the acoustic material pockets to make sure that all Acoustic Materials are intact.

8.3.3.7 Lubrication System Inspection

Check the dipstick to make sure the oil it is at the full level. Then inspect the rest of the Lubrication System to make sure there are no leaks. Note that if any class three leaks exist, the generator will be deadlined.

8.3.3.8 Fuel System Inspection

Inspect the Fuel System for leaks and damaged or missing parts. Note that if any leaks or other discrepancies exist, the generator will be deadlined.

8.3.3.9 Cooling Fan Inspection

Make certain the Cooling Fan is not damaged or loose and is in good working condition.

8.3.3.10 Radiator Cap and Hose Inspection

Inspect the Radiator Cap without removing it. Make sure there are no cracks in the Radiator Cap or the hoses.

8.3.4 Before Operations Check: Front

Refer to *Figure 6-45* for inspection points associated with before operations check – Front side.

Figure 6-45 – Before operations check – Front side.

8.3.4.1 Housing Inspection

Inspect the housing, door fasteners, and hinges just like you did for the rear and left sides of the generator. Note that the generator set will be deadlined if the doors cannot be secured.

8.3.4.2 Identification Plate Inspection

Check that the Identification Plates are secured and in place.

8.3.4.3 Types of Batteries

Check the battery type to see if they are maintenance free.

8.3.4.4 Electrolyte Levels

Check the electrolyte level of the batteries if they are not Maintenance Free Batteries.

8.3.4.5 Battery Inspection

Check the batteries for any damage or corrosion to the battery terminals and connections. Make sure the connections are secure. Note that the generator is deadlined if cables are loose, damaged, or missing.

8.3.5 Before Operations Check: Right Side

Refer to *Figure 6-46* for inspection points associated with before operations check – Right side.

Figure 6-46 – Before operations check – Right side.

8.3.5.1 Skid Plate Inspection

Inspect the Skid Base for corrosion and cracks.

8.3.5.2 Housing Inspection

Inspect the Engine Compartment housing, along with the Air Ducts and Exhaust Grills. You also need to check the door fasteners and hinges just like you did for the rear of the generator.

8.3.5.3 Identification Plate Inspection

Check that the Identification Plates are secured and in place.

8.3.5.4 Engine Compartment Inspection

Inspect the Engine Compartment for damage.

8.3.5.5 Engine Compartment Component Inspection

Inspect the Engine Compartment and look for loose or missing components.

8.3.5.6 Acoustic Material Inspection

Inspect the acoustic material pockets to make sure that all acoustic materials are intact.

8.3.5.7 Serpentine Belt Inspection

Check Serpentine Belt for cracks, fraying, or looseness.

8.3.5.8 Fuel Filter/Water Separator Inspection

Check the fuel filter and the water separator and drain off water and other contaminants.

8.3.5.9 Radiator Bottle Inspection

Check the Radiator Bottle for the proper coolant level and for leaks. Note that the generator will be deadlined if any class three leaks are present. Make sure to add coolant to the overflow bottle only. Never remove the radiator cap to fill the coolant. Removing the radiator cap could cause serious burns.

8.3.5.10 Exhaust System Inspection

Inspect the muffler and exhaust system for corrosion, damage, or missing parts. Note: Generator is deadlined if a discrepancy exists.

8.3.5.11 Ether Start System Inspection

Inspect the Ether start system and confirm that there are no missing or loose components.

8.3.5.12 Output Box Assembly Inspection

Inspect the Output Box Assembly for loose or damaged wiring or cables. Note, if cables, wires or hardware are damaged, the unit is deadlined until repairs are made.

8.3.5.13 Voltage Reconnection Board/Selector Switch Inspection

Ensure that the Voltage Reconnection Board and the voltage selection switch are positioned correctly.

8.3.6 Precautions Prior to Starting the TQG-B

You completed the before operations check using the Pre-Operations Checklist in the last section. Now you will learn about the controls and sequences and the safety precautions required to start the TQG-B generator. Other Seabees are relying on the power that you supply for their safety and their ability to operate necessary equipment. Failing to start the TQG-B could leave you and your fellow Seabees in the dark and vulnerable to the enemy.

Figure 6-47 – Ground rod warning.

8.3.6.1 Ground Rod Warning

Before learning how to start the TQG-B, take a moment to read this important safety warning. It is imperative for you to take this warning seriously. Remember, never attempt to start the generator set unless is properly grounded. The generator set produces high voltage it is in operation, and failure to comply can result in injury or death to personnel. See *Figure 6-47.*

8.3.6.2 Deadly Gases Warning

It is imperative for you to take this warning seriously. Never attempt to operate the generator set in an enclosed area unless exhaust discharge is properly vented outside. Exhaust discharge contains deadly gases including carbon monoxide. Failure to comply can cause injury or death to personnel. See *Figure 6-48.*

Figure 6-48 – Deadly gases warning.

8.3.7 Starting the TQG-B

Starting the TQG-B is a ten step process that you must be able to execute without the use of a checklist or other aid. Pay close attention to each step and you will be able to start the TQG-B quickly and correctly. Start up is conducted as follows:

- Turn the Dead Crank Switch to the NORMAL position.
- Place the Master Control Switch to the ON position.
- Ensure the Emergency Stop Switch is pulled out.
- Ensure the Battle Short Switch is in the OFF position.
- Scroll to Display Mode on the CIM and press SELECT using the keypad to continue to the FULL screen.

- Hold the Fault Reset Switch in the ON position and place the Engine Control Switch in the START position and hold no longer than fifteen seconds or until engine oil pressure reaches twenty-five PSI. Then release the Fault Reset Switch and the Engine Control Switch. NOTE: Never hold the Engine Control Switch in the START position for longer than 15 seconds. If utilizing an auxiliary fuel source, place the Engine Control Switch to PRIME & RUN AUX FUEL.
- Scroll to the FULL icon on the Display Mode of the CIM using the Keypad and press SELECT to display all generator set indicators.
- Adjust the voltage and frequency to the proper values using the Frequency Adjustment Switch and the Voltage Adjustment Switch.
- Allow the generator set to run with no load for five minutes for warm up. NOTE: Damage to the engine can occur if a load is applied before the engine warms up.
- Place the AC Circuit Interrupter Switch into the CLOSED position. This will apply energy to the load.

8.3.8 During Operations Check

It is very important to check some components of the TQG-B during operation. Performing the during operations check will ensure that the generator is running correctly. The generator set could be damaged if the during operations check is not done or done incorrectly. Refer to *Figure 6-49*.

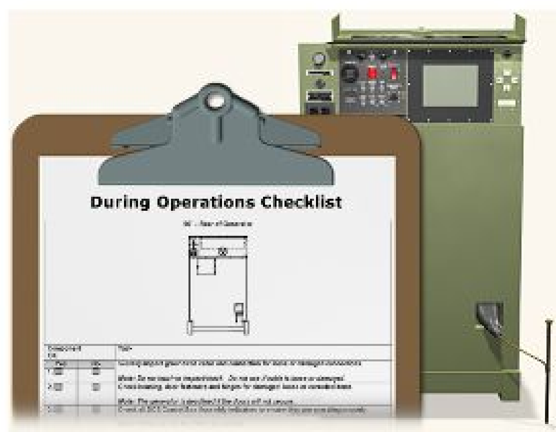

Figure 6-49 – During operations checklist.

The checklist gives guidance for a during operation exam of the generator. The During Operations Checklist covers all the components and instruments of the TQG-B that need to be checked while running. The during operations checklist:

- Reduces the likelihood of damage to the generator
- Allows you to identify maintenance issues before they become a problem
- Increases the chances of supplying power to those Seabees that need it when they need it

Before learning how to perform a during operations check, take a moment to read the following two safety warnings. It is imperative for you to take each warning seriously. Remember, never attempt to connect or disconnect load cables while the generator set is running. High voltage is produced when the generator set is in operation and failure to comply can result in injury or death to personnel.

It is imperative for you to take this warning seriously. Remember, personnel must wear hearing protection when operating or working near the generator set with any access door open. Failure to comply can cause hearing damage to personnel.

8.3.8.1 During Operations Check: Rear

We will now use the During Operations Checklist to perform the during operations check. Like the other checks, the during operations check is performed in a 360° rotation that starts at the rear of the generator. Here are the three steps required to inspect the rear side of the TQG-B when it is running.

- *Visually* inspect ground rod cable and connection for loose or damaged connections. Do not touch to inspect/check. Do not use if cable is loose or damaged.
- Check housing, door fasteners and hinges for damaged, loose or corroded items. The generator is deadlined if the doors will not secure.
- Check all DCS Control Box Assembly indicators to ensure they are operating properly. If indicators are not operating properly, the CIM is inoperative.

8.3.8.2 During Operations Check: Left

Now you will learn how to perform the second part of the 360° rotation by inspecting all necessary components on the left side of the TQG-B. There are six steps to inspect the left side of the TQG-B.

- Check the housing, door fasteners and hinges for damaged, loose, or corroded items. Check air ducts and exhaust grills for debris. The generator is deadlined if the doors will not secure or the debris cannot be cleared.
- Check that the Engine Compartment is not damaged.
- Check that the Engine Compartment has no loose or missing components.
- Check Lubrication System for leaks and damaged, loose or missing parts. If any Class III leaks or other discrepancies are present, the generator is deadlined.
- Check Fuel System for leaks, damaged, loose or missing parts. Any leaks or other discrepancies deadline the generator.
- Check for unusual noise being emitted from cooling fan area. If fan is damaged or loose, the generator is deadlined.

8.3.8.3 During Operations Check: Front

You have learned how to perform the steps of the during operations check on the Rear and Left Side of the generator. Now you will learn to inspect the Front of the TQG-B. There is only one step on the During Operations Check for the Front of the generator.

- Check housing, door fasteners and hinges for damaged, loose, or corroded items. The generator is deadlined if the doors will not secure.

8.3.8.4 During Operations Check: Right Side

You will now learn the final part of the 360° rotation by inspecting all necessary components on the Right Side of the TQG-B. There are four steps to inspect the right side of the TQG-B.

- Check the housing, door fasteners and hinges for damaged, loose, or corroded items. Check air ducts and exhaust grills for debris. The generator is deadlined if the doors will not secure or the debris cannot be cleared.
- Check that the Engine Compartment is not damaged.
- Check that the Engine Compartment has no loose or missing components.

- Check Radiator overflow bottle for leaks and missing parts. Generator is deadlined if a Class III leak is present. Cooling system operates at high temperature and pressure.

8.3.9 Shutting Down the TQG-B

Following the seven step process for shutting down the generator will prevent damage to vital equipment.

Shutting down the TQG-B is a seven step process that you must be able to execute without the use of a checklist or other aid. Pay close attention to each step and you will be able to shut down the TQG-B quickly and correctly. Refer to *Figure 6-50* for shutdown sequence.

Figure 6-50 – TQG-B generator shutdown sequence.

Step 1: Place the AC Circuit Interrupter Switch into the OPEN position until contactor on the CIM display screen reads open.

Step 2: Allow the engine to operate for approximately 5 minutes with no load applied to allow cooling off of the engine and AC generator.

Step 3: Scroll to EXIT on the CIM and select. After approximately 5 seconds the engine will stop.

Step 4: Place the Master Control Switch into the OFF position when the CIM screen displays a message that it is safe to turn off the computer.

Step 5: Place the Engine Control Switch into the OFF position.

Step 6: Turn the Panel Light Switch to the OFF position. Note: This step is not necessary if panel lights are already off.

Step 7: Place the Dead Crank Switch into the OFF position.

8.3.10 After Operations Checks

It is very important to check the components and instruments of the TQG-B after you operate it. Performing the after operations check will ensure that the generator is in good condition for its next use. The generator set could be damaged or fail to start if the after operations check is not done or done incorrectly. Refer to *Figure 6-51*.

The After Operations Checklist gives you guidance for a thorough after operation inspection of the generator and covers the components and instruments that need checking after operation. The After Operations Checklist is essential before operation of the TQG-B because it:

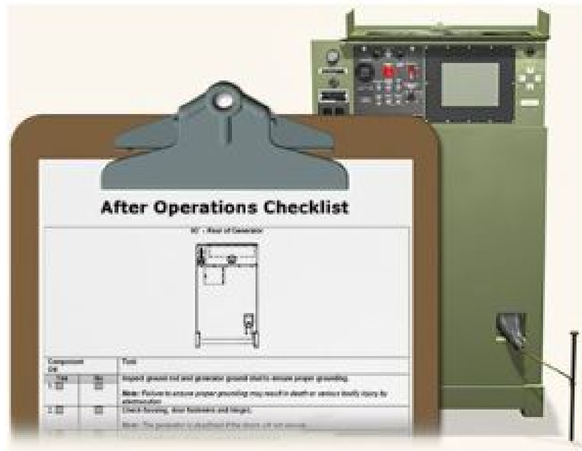

Figure 6-51 – After operations checklist.

- Reduces the likelihood of damage to the generator
- Allows you to identify maintenance issues

Before learning how to shut down the TQG-B, take a moment to read the following safety warning. It is imperative for you to take the warning seriously. Remember; avoid shorting any positive with ground/negative. DC voltages are present at generator set electrical components even with generator set shut down. Failure to comply can cause injury to personnel and damage to equipment.

8.3.10.1 After Operations Check: Rear

The after operations check is performed in a 360° rotation around the generator. We will begin by inspecting all components at the rear of the TQG-B. There are nine steps to inspect the rear side of the TQG-B.

- Inspect the Ground Rod and generator ground stud to ensure proper grounding. Failure to ensure proper grounding may result in death or serious bodily injury by electrocution.
- Check housing, door fasteners, and hinges. The generator is deadlined if the doors will not secure.
- Check Identification Plates are secured and in place.
- Check all indicators and controls for damaged or missing parts. If a discrepancy exists, the unit is deadlined.
- Check the Control Box harness for loose or damaged wiring. If a discrepancy exists, the unit is deadlined.
- Verify the DC Power Control Fuse is serviceable with a power rating of 10 AMPS.
- Verify the Frequency Selection Switch is positioned correctly. NORMAL = 60Hz NATO = 50 Hz
- Inspect the Parallel Cable and the cable connections for damage. This cable is used for parallel operation.

- Check air cleaner element or assembly for damage or restrictions. Generator is deadlined if the exhaust elements are clogged or the piping connections are loose.

8.3.10.2 After Operations Check: Left Side

There are ten steps to inspect the left side of the TQG-B.

- Check that the Skid Bases are not corroded or cracked.
- Check the housing, Air Ducts, Exhaust Grills, door fasteners and hinges. The generator is deadlined if the doors will not secure.
- Check Identification Plates are secured and in place.
- Check that the Engine Compartment is not damaged.
- Check that the Engine Compartment has no loose or missing components.
- Check that the Acoustical Materials are not missing or damaged.
- Check Lubrication System for leaks, oil level, or oil contamination. If any Class III leaks are present, the generator is deadlined.
- Check Fuel System for leaks, damaged, loose or missing parts. Any leaks or other discrepancies deadline the generator.
- Check Cooling Fan for damage or looseness. If fan is damaged or loose, the generator is deadlined.
- Check Radiator Cap and hoses for cracks and leaks.

8.3.10.3 After Operations Check: Front

The following five steps are required in performing the after operations check on the front of the generator.

- Check housing, door fasteners and hinges. The generator is deadlined if the doors will not secure.
- Check Identification Plates are secured and in place.
- Check to see if the unit has Maintenance Free Batteries. Both batteries need to be of the same type (maintenance free or electrolyte, do not mix the two). Maintenance free batteries are often recognizable by their lack of fill caps.
- Check electrolyte if the unit does not have Maintenance Free Batteries.
- Check batteries for damage or corrosion on connections and cables. Generator is deadlined if cables are loose, damaged or missing.

8.3.10.4 After Operations Check: Right Side

There are 13 steps to inspect the right side of the TQG-B.

- Check that the Skid Bases are not corroded or cracked.
- Check the housing, Air Ducts, Exhaust Grills, door fasteners and hinges. The generator is deadlined if the doors will not secure.
- Check Identification Plates are secured and in place.
- Check that the Engine Compartment is not damaged.
- Check that the Engine Compartment has no loose or missing components.

- Check that the Acoustical Materials are not missing or damaged.
- Check Serpentine Belt for cracks, fraying, or looseness. Generator is deadlined if the belt is broken or missing.
- Check Fuel Filter/Water Separator and drain off water and other contaminants.
- Check Radiator Bottle for leaks and coolant level. Generator is deadlined if a Class III leak is present. Add coolant to the overflow bottle ONLY. DO NOT remove the radiator cap.
- Check Muffler and Exhaust System for corrosion, damage, or missing parts. Generator is deadlined if a discrepancy exists.
- Check Ether Start System for missing or loose hardware.
- Check the Output Box Assembly for loose or damaged wiring or cables. If cables, wires or hardware are damaged, the unit is deadlined until repairs are made.
- Verify the Voltage Reconnection Board and the voltage selection switch are positioned correctly.

8.4.0 Operating the TQG-B in Parallel

It is very important to check components and indicators of the TQG-Bravo before operating in parallel. Performing the parallel operations check will ensure that both generators are paralleled without damaging equipment or injuring personnel.

8.4.1 Importance of the Parallel Operations Checklist

The Parallel Operations Checklist covers all the components and instruments of the TQG-B that need to be checked before paralleling. It also guides you through the process of paralleling two generator sets (See *Figure 6-52*).The parallel operations checklist is important because it:

- Reduces the likelihood of damage to the generator
- Guides you through the process of paralleling two generator sets

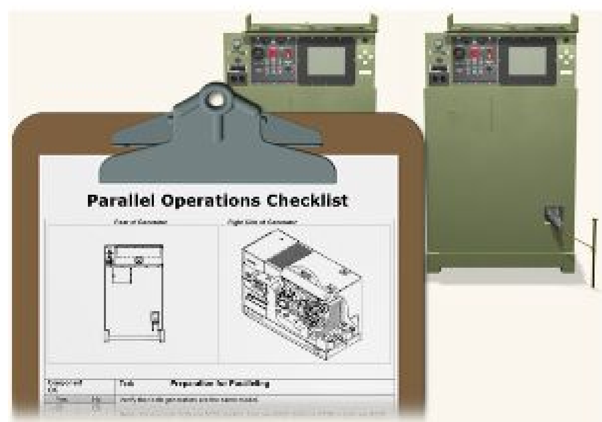

Figure 6-52 – Parallel operations checklist.

Before learning how to perform a parallel operations check, take a moment to read this important safety warning. It is imperative for you to take this warning seriously. Remember, make sure there is no input to the load output terminal board and the generator sets are shut down before making any connections for parallel operation or moving a generator set which has been operating in parallel. Failure to comply can cause injury or death to personnel by electrocution.

8.4.2 Parallel Operations Check

We will now use the parallel operations checklist to perform the parallel operations check. The parallel operations check will prepare and start the generators, then apply power from both generators to the load. There are eighteen steps total on the Parallel Operations Checklist, which we have broken up into two groups. We will begin with the first four steps which prepare the generator for parallel operations. These four steps are to be performed in sequence. Refer to *Figure 6-53* for sequence.

Figure 6-53 – Parallel operations checks.

Step 1: Make sure that both generators are the same model. Examples would be two 805 bravos, 806 bravos, 815 bravos, or 816 bravos. Never try to parallel two different models of generators.

Step 2: Conduct a before operations check using the Pre Operations Checklist on each generator set.

Step 3: Verify the frequency selection switch is set to NORMAL, 60 hertz if you are operating at normal frequency and NATO 50 hertz if operating at NATO frequency.

Step 4: Verify the voltage selection switch of each generator was positioned correctly during setup.

The last part of the Parallel Operations Checklist provided steps for preparing the generators for parallel. The next part guides you through the procedures for achieving parallel operations for the two generator sets. Refer to *Figure 6-54* for sequence.

Figure 6-54 – Parallel operations sequence.

Step 5: Designate Set #1

Step 6: Designate Set #2

Step 7: Verify that the load cable is rated at an amperage high enough to handle maximum load. The TQG-Bravo model's highest Amperage is 208 Amps.

Step 8: Connect the parallel cable to each parallel receptacle and connect the load cables to each load stud on each generator load terminal board.

Step 9: Verify that both generators are connected to the power distribution system.

Step 10: Conduct the 10 step starting procedures for both generators.

Step 11: Verify that the CIM on each generator is displaying the FULL mode screen.

Step 12: Adjust Set #1 to the proper voltage, and then adjust Set #2 to the same voltage as Set #1.

Step 13: Adjust Set #1 to the proper frequency and then adjust Set #2 to the same frequency as Set #1. Carefully adjust the frequency; too much adjustment can cause the generator to go into reverse power.

Step 14: Close AC CIRCUIT INTERRUPT switch on Set #1 and on Set #2. The generators are now running in parallel with no load.

Step 15: Verify that the POWER gauge on both sets reads “zero”.

Step 16: Close the circuit breaker on the power distribution system. The generators are now supplying power to the load.

Step 17: Verify that the GEN CURRENT indicators on BOTH generators are approximately the same. If not, adjust the VOLTAGE ADJUST switch up or down to achieve the proper balance. One generator may have to be adjusted upward, while the other may have to be adjusted downward.

Step 18: Verify that POWER readings from both CIM displays are within 10% of each other. If readings are not within 10% of each other, remove generators from load, shut down, and notify the next level of maintenance.

Summary

Power generation is an important factor in the accomplishment of your job as a Construction Electrician. As an electrician, there will be times when it is necessary to set up portable generators to accomplish the mission. Establishment of a reliable power source is imperative to the start of any construction project. Without it, no other work or construction can begin. From generator selection to site approval, sheltering, and grounding of equipment, your job is to get the power running. As a CE, you will be tasked to maintain these generators, either as a watch or maintenance crew. Your job is to be familiar with manufacturer's manuals, maintenance issues, and servicing requirements. Another factor to consider is the setup and establishment of power, either through single or parallel operations. Remember, power is necessary to commence any construction project.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

*Unified Facilities Criteria (*UFC*) 3-560-0*1 (Electrical Safety, Operation and Maintenance)

OSHA Regulations (Standards – 29 CFR)

American National Standards Institute (ANSI Z89.2-1971)

Naval Construction Force Manual, *NAVFAC P-315*, Naval Facilities Engineering Command, Washington, D.C., 1985.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook,* 22d ed, McGraw-Hill, NY, 2008.

Operator and Organization Maintenance Manual for a Generator Set, Diesel Engine Driven, TM5-6115-545-12, 1982.

TQG-B Generator set Computer Based Training (CBT) product.