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Preface

Electric power generation in the field is vital to the support of the AirLand Battle doctrine. Field Manual (FM) 20-31 provides information about the engine-driven electrical generator sets used by the Department of Defense (DOD) in the field. These generators produce from 0.5 to 500 kilowatts (kw) of electricity and are designed to meet most military needs. Topics discussed in the manual include the types of generators available and how to select, install, connect, operate, and maintain them. Fuel supplies, safety procedures, and first aid treatment for electric shock victims are also discussed. The last chapter describes demolition procedures required to deny enemy takeover of equipment.

This manual is intended for all levels of generator set operators, their supervisors, and maintenance personnel. Operations personnel can use the manual as a planning guide.

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Unless otherwise stated, whenever the masculine or feminine gender is used, both men and women are included.

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Chapter 1

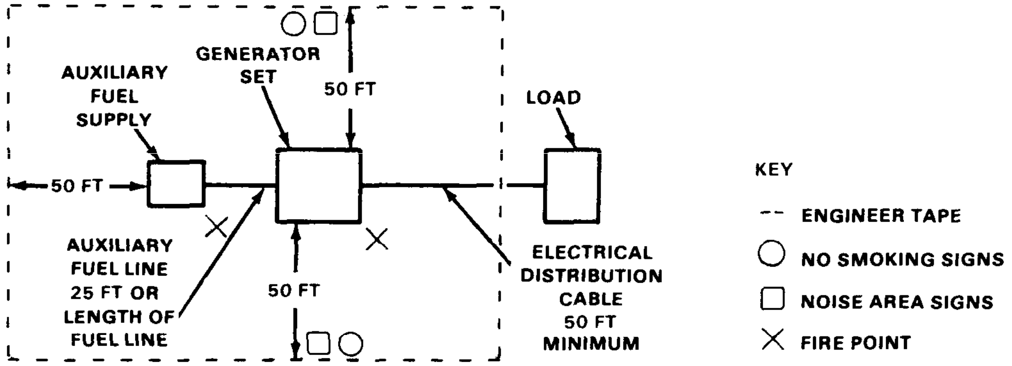
Electric Power Generation and Distribution Systems

The DOD uses a family of generator sets to produce the electric power needed by military field units. The family was developed in the 1960s to reduce the variety of generator sets and repair parts required by all services. Field Manual. 20–31 describes the generators in this family and provides instructions for their use.

The demands for electricity in military field operations are numerous and varied. Electricity powers equipment ranging from rock crushers to missile launchers. It services aircraft, ships, and land vehicles. Electricity is required for command and control operations, medical support, and other facilities. The mobile generator sets used by DOD to meet these demands are described in this chapter.

MOBILE GENERATOR SETS

A mobile electric generator set converts mechanical energy to electrical energy by using an engine to drive the generator. An internal fuel supply makes the set independent and mobile. When equipped with accessories such as an electrical distribution system, these sets can produce all the power needed by military forces in the field. The elements of an electric power generating site in the field are shown below.



TYPICAL ELECTRIC POWER GENERATING SITE

The generator models in the DOD inventory and their characteristics are listed in the table below. The kilowatts of power each model produces, their frequency rating (in cycles per second), and voltage (output) also are listed. The rated current of DC generators is shown in the output column. The characteristics in the table must match the requirements of the equipment to which the generator set is connected.

GENERATOR SET CHARACTERISTICS

MODEL	KILOWATT	FREQUENCY	OUTPUT
MEP-014A	0.5	60	120/240 volts (v), single-phase, three-wire
MEP-024A	0.5	DC	28v, 17 amperes (amps)
MEP-019A	0.5	400	120/240v, single-phase, three-wire
MEP-015A	1.5	60	120/240v, single-phase, three-wire
MEP-025A	1.5	DC	28v, 53 amps
MEP-016A	3	60	120v, three-phase 120/240v or 120/208v, three-phase, four-wire
MEP-021A	3	400	120v, three-phase 120/240v or 120/208v, three-phase, four-wire
MEP-026A	3	DC	28v, 103 amps
MEP-002A	5	60	120v, three-phase, three-wire 120/240v or 120/208v, three-phase, four-wire
MEP-017A	5	60	120v, three-phase, three-wire 120/240v or 120/208v, three-phase, four-wire
MEP-022A	5	400	120v, three-phase, three-wire 120/240v or 120/208v, three-phase, four-wire
MEP-018A	10	60	120v, three-phase, three-wire 120/240v or 120/208v, three-phase, four-wire
MEP-023A	10	400	120v, three-phase, three-wire 120/240v or 120/208v, three-phase, four-wire
MEP-003A	5	60	120v, three-phase, three-wire 120/240v or 120/208v, three-phase, four-wire
MEP-112A	10	400	120v, three-phase, three-wire 120/240v or 120/208v, three-phase, four-wire
MEP-004A	15	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-103A	15	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-113A	15	400	120/208v or 240/416v, three-phase, four-wire
MEP-005A	30	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-104A	30	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-114A	30	400	120/208v or 240/416v, three-phase, four-wire
MEP-006A	60	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-105A	60	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-115A	60	400	120/208v or 240/416v, three-phase, four-wire

GENERATOR SET CHARACTERISTICS (CONTINUED)			
MODEL	KILOWATT	FREQUENCY	OUTPUT
MEP-404B	60	400	120/208v or 240/416v, three-phase, four-wire
MEP-007A	100	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-007B	100	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-106A	100	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-116A	100	400	120/208v or 240/416v, three-phase, four-wire
MEP-009A	200	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-108A	200	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-029A	500	50/60	120/208v or 240/416v, three-phase, four-wire
MEP-029AHK	500	50/60	120/240v or 120/208v, three-phase, four-wire

The table below shows the generator models separated by the type of engine that drives the generator. This table-lists the application (use) for each model and the technical manual (TM) that provides additional information about it.

MOBILE ELECTRIC GENERATOR SETS				
MODEL	KILOWATT	APPLICATION	VOLTAGE	TECHNICAL MANUAL
GASOLINE ENGINE DRIVEN				
MEP-014A	0.5	Utility	AC	TM 5-6115-329-14
MEP-019A	0.5	Utility	AC	TM 5-6115-329-14
MEP-024A	0.5	Utility	DC	TM 5-6115-329-14
MEP-015A	1.5	Utility	AC	TM 5-6115-323-14
MEP-025A	1.5	Utility	DC	TM 5-6115-323-14
MEP-016A	3	Utility	AC	TM 5-6115-271-14
MEP-021A	3	Utility	AC	TM 5-6115-271-14
MEP-026A	3	Utility	DC	TM 5-6115-271-14
MEP-017A	5	Utility	AC	TM 5-6115-332-14
MEP-022A	5	Utility	AC	TM 5-6115-332-14
MEP-018A	10	Utility	AC	TM 5-6115-275-14
MEP-023A	10	Utility	AC	TM 5-6115-275-14
DIESEL ENGINE DRIVEN				
MEP-002A	5	Utility	AC	TM 5-6115-584-12
MEP-003A	10	Utility	AC	TM 5-6115-585-12
MEP-112A	10	Utility	AC	TM 5-6115-585-12
MEP-004A	15	Utility	AC	TM 5-6115-464-12
MEP-103A	15	Precise	AC	TM 5-6115-464-12
MEP-113A	15	Precise	AC	TM 5-6115-464-12
MEP-005A	30	Utility	AC	TM 5-6115-465-12
MEP-104A	30	Precise	AC	TM 5-6115-465-12
MEP-114A	30	Precise	AC	TM 5-6115-465-12
MEP-006A	60	Utility	AC	TM 5-6115-545-12
MEP-105A	60	Precise	AC	TM 5-6115-545-12
MEP-115A	60	Precise	AC	TM 5-6115-545-12

MOBILE ELECTRIC GENERATOR SETS (CONTINUED)				
MODEL	KILOWATT	APPLICATION	VOLTAGE	TECHNICAL MANUAL
DIESEL ENGINE DRIVEN				
MEP-007A	100	Utility	AC	TM 5-6115-457-12
MEP-007B	100	Precise	AC	TM 5-6115-457-12
MEP-106A	100	Precise	AC	TM 5-6115-457-12
MEP 116A	100	Precise	AC	TM 5-6115-457-12
MEP-009A	200	Utility	AC	TM 5-6115-458-12
MEP 108A	200	Precise	AC	TM 5-6115-458-12
MEP 029A	500	Utility	AC	TM 5-6115-593-12
MEP 029AHK	500	(with options)	AC	TM 5 6115 593-12
TURBINE ENGINE DRIVEN				
MEP 404B	60	Precise	AC	TM 5-6115-603-12

Electric generator sets are driven by gasoline, diesel, or gas turbine engines. The generators produce either alternating current (AC) or direct current (DC). Alternating current changes in value and reverses its direction of flow at regular intervals. Direct current is constant in value and flows only in one direction.

AC Generator Sets

The lighting and power loads of most field units require voltages and frequencies supplied by AC systems. While 60-cycle AC is used much of the time, loads with specific voltage, frequency, and power requirements must use 400–cycle AC. Radar, fire control sets, communication controls, and guided–missile systems are examples of equipment requiring 400-cycle AC. Some equipment can operate with either 60-cycle or 400–cycle AC.

Small AC generator sets are driven by gasoline engines and. produce from 0.5 kw to 1.5 kw of electricity. The output is delivered in 120 volts or 240 volts, with a single-phase distribution system, and at a frequency of 60 cycles. Sets that produce 0.5 kw are available at a frequency of 400 cycles, and those that produce 1.5 kw are available at a frequency of 60 cycles.

The 1.5-kw, 60-cycle generators are the most versatile and widely used small sets in the DOD inventory. They satisfy the communications and lighting needs of small field units.

Medium–sized AC generator sets are driven by gasoline or diesel engines and produce between 3 kw and 10 kw of electricity. These generator sets can deliver 60– or 400–cycle AC. A reconnection switch enables the operator to connect any of the following distribution systems at the rated kilowatt output:

- Single-phase, two–wire, 120 volts.
- Single–phase, two–wire, 240 volts.
- Three-phase, three-wire, 120 volts.
- Three-phase, four-wire, 120/208 volts.

Generator sets that produce 60–cycle AC are used for general power requirements because they are versatile and have a range of power outputs. Sets that produce 10 kw at 60 cycles are the most versatile because their outputs are adequate for small maintenance shops and other relatively large loads. These generators usually are mounted on skids to increase their mobility.

Large AC generators are driven by diesel engines and produce 15, 30, 60, 100, 200, or 500 kw of electricity. These generators can deliver 50/60- or 400-cycle AC. They can deliver three-phase, four-wire power at either 120/208 volts or 240/416 volts. An output delivered at 50 cycles Is 82 percent of the rated power. An output delivered at 60 cycles is 100 percent of the rated power.

Large generator sets produce electricity for lighting and power in buildings and other general loads. They can produce enough output to supply several kinds of loads simultaneously over a relatively wide area.

Standard frequency generator sets are rated at 50/60 cycles. High-frequency generator sets are rated at 400 cycles. The most common gas turbine engine–driven generator set produces 60 kw of electricity at 400-cycle AC.

The AC generator sets are designed to operate at various voltages, frequencies, and power levels. To meet a particular power demand, an operator must choose a set with the proper characteristics. If a large set is needed but is not available, several small sets, each located near the load to be supplied, may be used. Note that additional operators and maintenance personnel may be required if several small sets replace a large one.

Mobility is a factor in selecting generator sets for field use. Sets that produce 60 kw of electricity often are used in the field because they can be transported in 2 l/2-ton trucks. Sets that produce more than 60 kw of power must be transported in 5-ton trucks. Therefore, a field unit may make parallel connections between several 60–kw generator sets to produce an amount of power equivalent to one large set.

DC Generator Sets

The DC generator sets provide power for specific pieces of equipment. For example, DC generators are used to charge batteries, operate communications equipment, and provide power to some missile equipment. Thus, the need for DC generator sets in the field Is less than the need for AC sets. The three DC sets listed in the tables on pages 2 and 3 are basic AC generators that use rectifiers to convert the AC voltage to DC voltage.

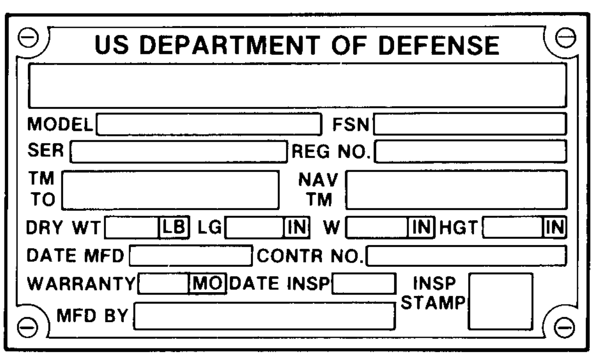
Data Plates

Three data plates provide information about the output from a generator set. These plates indicate all pertinent information about a generator set's capabilities and performance characteristics. Refer to the description and data section in the appropriate technical manual for information about a specific generator that is not on the plates.

Alternator data plate. Specifies the alternator ratings for 50-, 60-, and 400–cycle outputs. The plate also provides serial numbers, kilowatt ratings, DC excitation requirements, date of manufacture, voltage and ampere outputs, power factors, model numbers, and revolutions per minute (RPM). On most models the plate is attached to the main generator housing.

Engine identification plate. Specifies the engine model number, serial number, horsepower rating, date of manufacture, number and firing order of the cylinders, national stock number, and contract number. Sometimes the applicable technical manual number is shown. This plate usually is attached to the engine.

Starting and stopping instruction plate. Sometimes called the paralleling and synchronizing instruction plate, this plate specifies starting and stopping and/or paralleling and synchronizing procedures. Preliminary positioning of controls and procedures for using the dark lamp method of synchronizing and paralleling generators also may be shown. This plate is inside the main control panel cover.



TYPICAL DATA PLATE

ELECTRIC DISTRIBUTION SYSTEMS

A distribution system transfers electricity from its source in the generator to loads such as heaters, motors, or lights. A distribution system is identified by the number of phases, the number of wires, and the voltages between wires. Operators must check the data plates on the equipment before connecting a distribution system to the load. Any attempt to operate equipment at other than its rated frequency will damage it. The following distribution systems are used by military field units:

- Single-phase, two-wire.
- Single-phase, three-wire.
- Three-phase, three–wire.
- Three-phase, four–wire.

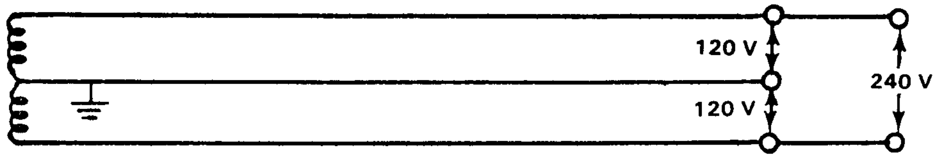
Single-Phase, Two-Wire

In a single-phase, two-wire distribution system, one of the two wires from the generator set is connected to the ground (neutral wire). The neutral wire is called the grounded wire or the grounded circuit conductor.

The second wire, called the live wire or ungrounded conductor, is connected to the load. Usually there is a difference of 120 volts between these two wires. Any single-phase, two–wire, 120-volt load can be connected to both the live wire and the grounded wire.

Single-Phase, Three-Wire

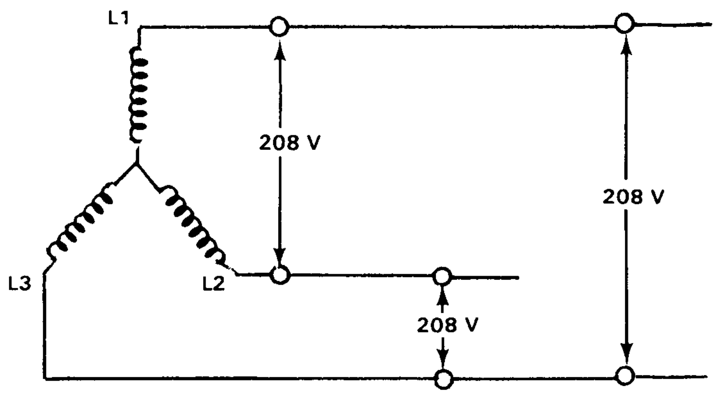
A single-phase, three–wire distribution system has one grounded wire and two live wires (figure at the top of page 8). It is called a single-phase system because there is no phase difference between the two available voltages. The difference in voltage between either of the two live wires and the grounded wire usually is 120 volts. The difference in voltage between the two live wires is 240 volts.



SINGLE-PHASE, THREE-WIRE, 120/240-VOLT SYSTEM

Three-Phase, Three-Wire

All three wires in a three-phase, three–wire system are live wires. Thus, a three-phase, three–wire, 120-volt load can be connected to all three wires. This system requires a generator set designed to produce three-phase voltage. Because only one magnitude of voltage is available from this kind of generator, the loads must require the same voltage.

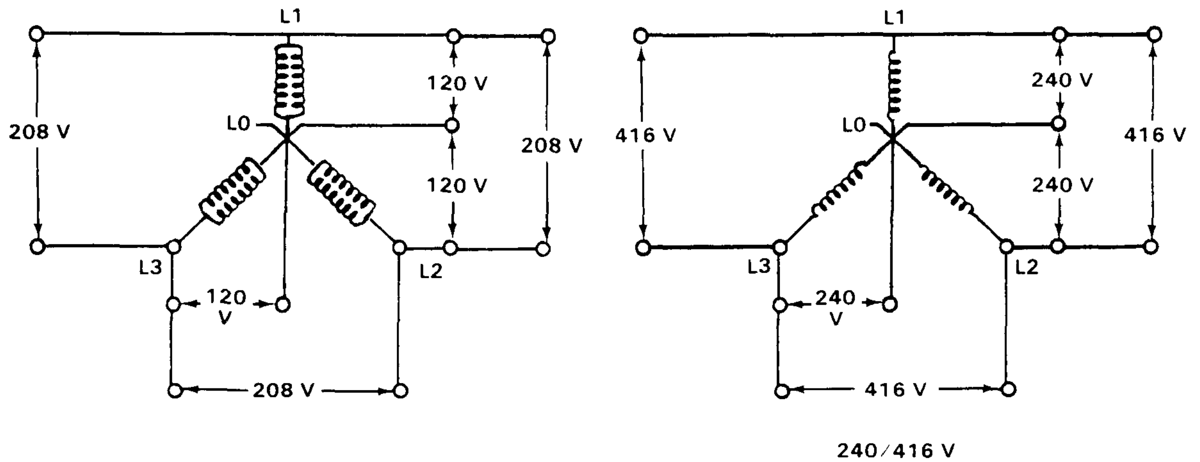


THREE-PHASE, THREE-WIRE SYSTEM

Three–Phase, Four-Wire

A three-phase, four-wire system is shown in the figure on page 9. A generator set with this system may be designed to produce single-phase or three-phase voltages. For example, the generator could produce 120 volts and 208 volts, or 240 volts and 416 volts. A 240/416 voltage connection is common on generator sets that produce from 15 kw through 500 kw of electricity.

Generator sets with three–wire or four–wire systems are designed so that the ratio of the higher (line) voltage to the lower phase (voltage) is always the same and cannot be changed (1.73 x phase voltage = line



THREE-PHASE, FOUR-WIRE SYSTEM

voltage). Thus, any single-phase, two-wire, 120-volt load can be fed power by making a connection between any live wire and the grounded wire. Any single–phase, two-wire, 208–volt load can be fed between any two live wires. A single-phase, three-wire, 120/208–volt load can be fed by making a connection to two live wires and the grounded wire. Any three-phase, four–wire, 120/208-volt load can be fed power by making a connection to all four wires. Any three–phase, three–wire, 240-volt load can be fed by repositioning the tap change board and the connection to the three live wires.

Distribution systems are classified according to the voltage used to carry the power from the power source to the distribution transformers or to the loads. The following distribution systems commonly are used in military field units:

- Single-phase, two-wire, 120–volt system. Supplies electricity for light bulbs, portable tools, and most equipment requiring low power.
- Single-phase, three-wire, 120/240–volt system. Supplies power directly to small loads such as lighting in barracks.
- Three-phase, four-wire, 120/208-volt system. Supplies power to structures that require substantial amounts of power and lighting, such as shops and hospitals. This system is more flexible than either of the systems discussed previously.
- Three–phase, three–wire, 240/416-volt system. Supplies power to loads in structures in which the three-phase power load is larger than the single–phase lighting load. The single-phase lighting load in such a structure is supplied either from a separate single phase service to the structure or by a stepdown transformer.

Chapter 2

Generator Selection and Operation Principles

Selecting the generators that can produce the power required by a field unit is an important function. The operator or person responsible for this function must select the number and types of generators that can best meet the unit's needs. The tasks and factors that govern the selection process are described in this chapter. Some basic operations required for power generation in the field also are described. Preliminary tasks that must be completed before power generating equipment is selected are computing the load, computing the cable size, and balancing the load required for the field unit.

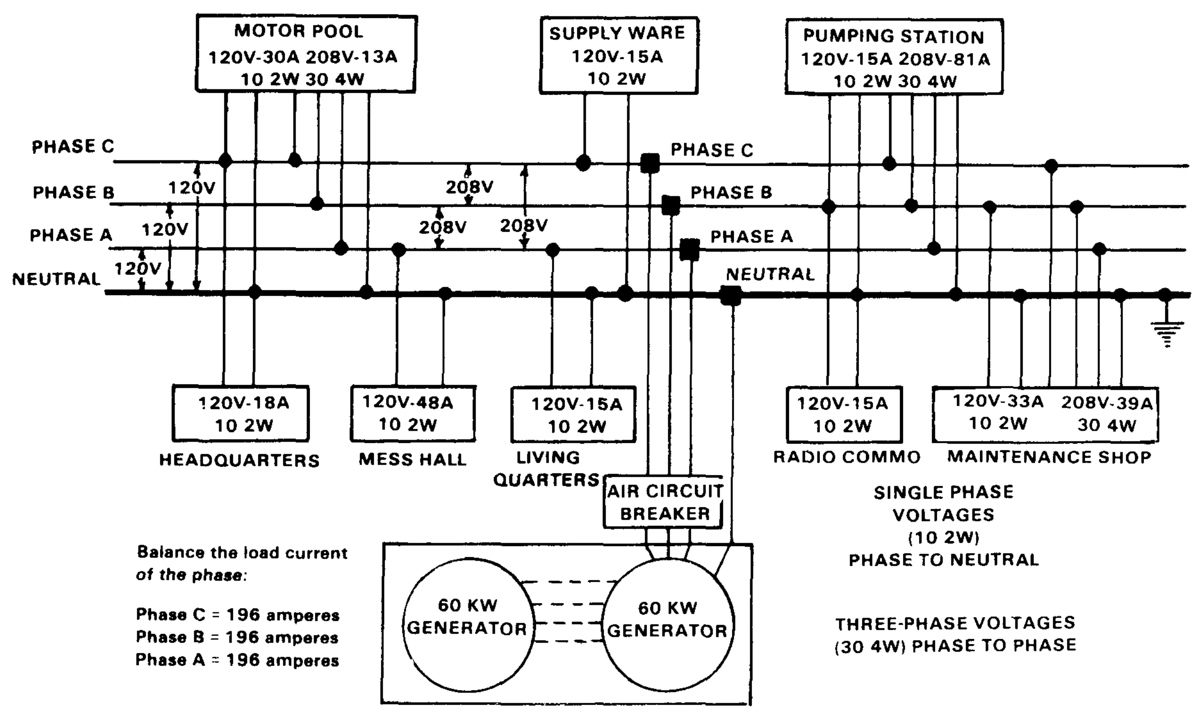
COMPUTING THE LOAD

An accurate estimate of the load requirement is needed before a field unit's power distribution system can be designed properly. The estimated load is determined from the size and location of the load. Complete the following steps to determine the field unit's load requirement:

Map the field unit.
Locate and mark each structure that requires electric power on a map. Identify each structure, such as barrack, recreation hall, or warehouse, as shown in the figure on page 11.

Determine the electrical load for each area.
Electrical loads usually are measured in amperes (amps), kilowatts, or kilovolt–amperes. The total electrical load fluctuates constantly as equipment starts and stops.

Compute the connected load.
The connected load for each structure is computed from the electrical load. The connected load should total the wattage required for all lights and electrical devices plus the total horsepower of all motors. The connected load usually is measured in kilowatt–amperes.



LOAD REQUIREMENTS OF A MILITARY FIELD INSTALLATION

Compute the demand load.
The demand load, computed from the connected load, is the maximum demand required to serve a connected load. The demand load usually is less than the connected load because all equipment in a building, seldom operates at one time. The ratio between the estimated maximum demand load and the connected load is the demand factor. Note that the demand load is never greater than the connected load. The demand and connected loads may be the same if the mission of a tactical shop requires that all electrical equipment be operated simultaneously.

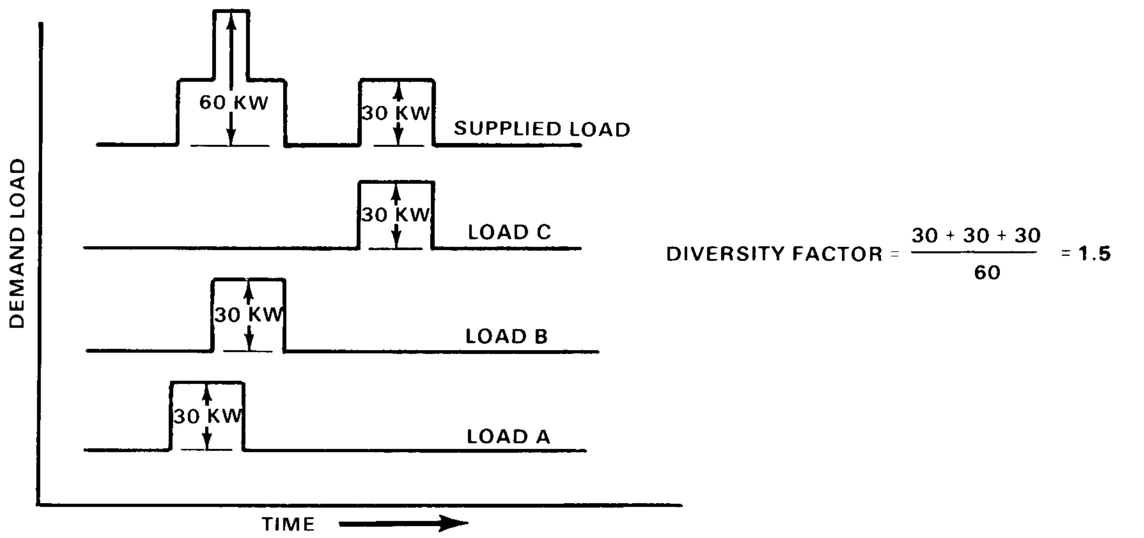
The demand factors established for the design of several types of military structures are listed in the table on page 12. Use the following formula to determine the demand load when the demand factor is known:

Demand load = connected load x demand factor.

Compute the diversity factors.
Measured at the point of supply, the diversity factor is the ratio of the sum of the maximum power demands for the component parts of a system to the maximum demand of the entire system. The diversity factor is similar to the demand factor except that it deals with the actual demand load not the potential demand load. For example, a generator set may serve three

DEMAND FACTORS	
STRUCTURE	DEMAND FACTOR
Housing	.9
Aircraft maintenance facilities	.7
Operation facilities	.8
Administrative facilities	.8
Shops	.7
Warehouses	.5
Medical facilities	.8
Theaters	.5
NAV aids	.7
Laundry, ice plants, and bakeries	1.0
All others	.9

demand sites, each with a maximum demand of 30 kw, as shown in the figure below. In this example, the potential demand load is 90 kw. Because the maximum demands at the three sites do not occur simultaneously, the maximum demand load on the generator set is only 60 kw, not 90 kw. In this example the diversity factor is computed as: $\frac{90}{60} = 1.5$.



DIVERSITY FACTOR

Demand and diversity factors are used in planning the design of electrical facilities. They are used to determine the type and size of generator sets required for a field unit. Demand factors also are used to rearrange existing facilities. For example, additional equipment may greatly increase the connected load for a structure, but it may or may not require a change to the serving generator set.

The diversity factors of significant loads must be considered when they contribute to peak loads. Loads that occur at peak load times may affect the capacity required for a generator set, while loads that occur at nonpeak times may not. For example, a dining facility may contribute about 25 percent of its actual electrical load to the peak load of the system.

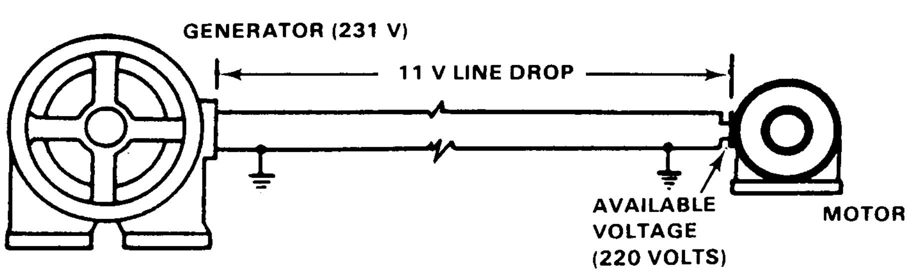
Compute the power factors.
The power factor of an anticipated load must be determined before the amount of power required for an area can be estimated accurately. All AC power estimates are calculated using equipment power factor ratings whenever possible. Noninductive loads such as lights, heaters, and soldering irons are computed at a power factor of 1.0. Inductive loads such as partially loaded transformers and induction motors produce a power factor less than 1.0 because they introduce inductive reactance. The sum of the inductive and noninductive loads is the connected load for the entire installation.

The power factor of an AC circuit is the ratio of the true power (watts) to the apparent power (volt-amperes), as shown in the following formula:

$$\text{Power factor} = \frac{\text{watts}}{\text{volt-amperes}}.$$

The power delivered by a DC generator set (in watts) is the product of the current multiplied by the voltage. There is no inductive reactance in a DC circuit regardless of the character of the load.

Compute the voltage drop.
A voltage drop is the difference between the amount of voltage at the input and output ends of a transmission line. A voltage drop, sometimes called the line loss, is caused by the resistance of the line.



TYPICAL LINE VOLTAGE DROP

Line loss is expressed either as a percentage of the voltage required at the receiving end or as a percentage of the voltage applied by the generator to the line. The example in the figure on page 13 shows a generated voltage of 231 volts, a receiving end voltage of 220 volts, and a line loss of 11 volts. The voltage loss or drop expressed as a percentage of the voltage at the receiving end is 11/220 or 5 percent. The voltage loss, expressed as a percentage of the voltage from the generator end in this example, is 11/231 or 4.8 percent of the sending end voltage. The percentage loss or drop is usually shown as a percentage of the voltage required at the receiving end.

The maximum allowable drop for lighting and power loads, as stated in the National Electrical Code, is 5 percent. This allows no more than a 3-percent loss in the branch lines and no more than a 2–percent loss in the main and feeder lines.

To increase the voltage at the receiving end of the distribution system, increase the voltage output from the generator set. However, the output should never exceed the voltage rating of the generator set. Operators must monitor the voltage throughout the distribution system periodically to identify and correct malfunctions in electrical equipment connected to the lines.

A calculated voltage drop is used to plan a distribution system. A system that does not produce enough voltage may cause unexpected results. For example, the heat produced by resistive heating equipment varies as the voltage varies. Thus, a system operating at 10 percent below the rated voltage will produce 19 percent less heat. The heat loss is absorbed by the conductors supplying the power and may cause conductor failure.

Allow for growth.
Expect the power demands on an electrical circuit to increase in the future. Allow a growth of at least 50 percent of the initial load. When installing a wiring system for electric power, ensure the circuit can accommodate at least 50 percent more than the actual connected loads.

COMPUTING THE CABLE SIZE

A cable connects the generator set to the load. The size of this cable affects the efficiency of the generator. Power losses will occur along the transmission line if the cable is too small. The load current carried by the cable and the distance between the generator set and the load are used to determine the correct cable size.

When a conductor is too small in diameter to carry the current demanded, the cable may overheat and cause the insulation to burn. If the cable wires melt, the circuit will break. The amount of resistance to current flow that occurs along the cable is determined by the distance between the generator set and the load.

Complete the following steps in sequence to determine the cable size required:

1. Use the following tables to compute the total current demand for each phase:

LOAD CONVERSION FACTORS			
TO FIND	DIRECT CURRENT	ALTERNATING CURRENT	
		SINGLE PHASE	THREE PHASE
Amperes when horse-power is known	$\frac{HP \times 746}{E \times Eff}$	$\frac{HP \times 746}{E \times Eff \times PF}$	$\frac{HP \times 746}{1.73 \times E \times Eff \times PF}$
Amperes when kilo-watts are known	$\frac{KW \times 1000}{E}$	$\frac{KW \times 1000}{E \times PF}$	$\frac{KW \times 1000}{1.73 \times E \times PF}$
Amperes when kilovolt-amps are known		$\frac{Kva \times 1000}{E}$	$\frac{Kva \times 1000}{1.73 \times E}$
Kilowatts when-amperes are known	$\frac{I \times E}{1000}$	$\frac{I \times E \times PF}{1000}$	$\frac{I \times E \times 1.73 \times PF}{1000}$
Kilowatts when horse-power is known	$\frac{HP \times 746}{1000 \times Eff}$	$\frac{HP \times 746}{1000 \times Eff}$	$\frac{HP \times 746}{1000 \times Eff}$
Kilovolt-amps when amperes are known		$\frac{I \times E}{1000}$	$\frac{I \times E \times 1.73}{1000}$
Kilovolt-amps when horsepower is known		$\frac{HP \times 746}{1000 \times Eff \times PF}$	$\frac{HP \times 746}{1000 \times Eff \times PF}$
Horsepower output when amperes are known	$\frac{I \times E \times Eff}{746}$	$\frac{I \times E \times Eff \times PF}{746}$	$\frac{I \times E \times 1.73 \times Eff \times PF}{746}$
Load power factor when rated horsepower and kilovolt-amps are known		$\frac{HP \times 746}{100 \times Kva \times Eff}$	$\frac{HP \times 746}{100 \times Kva \times Eff}$

I = amperes; E = volts; Eff = Efficiency (as a decimal); PF = power factor (as a decimal); KW = kilowatts; Kva = kilovolt-amperes; HP = horsepower.

Three phase, AC lines are assumed to be feeding balanced, three-phase loads.

For three-phase loads, input current is per phase.

WATTAGE CONSUMPTION OF ELECTRICAL APPLIANCES

APPLIANCE	AVERAGE WATTAGE	APPLIANCE	AVERAGE WATTAGE	APPLIANCE	AVERAGE WATTAGE
Clock	3	Grill	600	Refrigerator	500
Coffeemaker	1000	Hotplate	1250	Radio	100
Fan, 8-inch	30	Humidifier	500	Soldering iron	200
Fan, 10-inch	35	Iron	1000	Television	300
Fan, 12-inch	50	Mixer	200	Toaster	1200
Heater (radiant)	1300	Phonograph	40	Washing machine	1200
Griddle	450	Range	8000	Water heater	4500

FULL-LOAD CURRENTS OF MOTORS

HP	120V	240V
1/4	2.9	1.5
1/3	3.6	1.8
1/2	5.2	2.6
3/4	7.4	3.7
1	9.4	4.7
1 1/2	13.2	6.6
2	17	8.5
3	25	12.2
5	40	20
7 1/2	58	29
10	76	38
15		55
20		72
25		89
30		106
40		140
50		173
60		206
75		255
100		341
125		425
150		506
200		675

These values of full-load current are average for all speeds, and are in accordance with the National Electrical Code.

HP	115V	230V
1/8	4.4	2.2
1/4	5.8	2.9
1/3	7.2	3.6
1/2	9.8	4.9
3/4	13.8	6.9
1	16	8
1 1/2	20	10
2	24	12
3	34	17
5	56	28
7 1/2	80	40
10	100	50

These values of full-load current are in accordance with the National Electrical Code, and are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may requre more running current, in which case the nameplate current rating should be used.

For full-load currents of 208- and 200-volt motors, increase the corresponding 230-volt motor full-load current by 10 and 15 percent, respectively.

FULL-LOAD CURRENTS OF MOTORS (CONTINUED)

INDUCTION TYPE SQUIRREL-CAGE AND WOUND MOTOR AMPERES					SYNCHRONOUS TYPE UNITY POWER FACTOR† AMPERES				
HP	110V	220V	440V	550V	2300V	220V	440V	550V	230V
½	4.0	2.0	1.0	0.8					
¾	5.6	2.8	1.4	1.1					
1	7.0	3.5	1.8	1.4					
1½	10.0	5.0	2.5	2.0					
2	13.0	6.5	3.3	2.6					
3		9.0	4.5	4.0					
5		15.0	7.5	6.0					
7½		22.0	22.0	9.0					
10		27.0	14.0	11.0					
15		40.0	20.0	16.0					
20		52.0	26.0	21.0					
25		64.0	32.0	26.0	7.0	54.0	27.0	22.0	5.4
30		78.0	39.0	31.0	8.5	65.0	33.0	26.0	6.5
40		104.0	52.0	41.0	10.5	86.0	43.0	35.0	8.0
50		125.0	63.0	50.0	13.0	108.0	54.0	44.0	10.0
60		150.0	75.0	60.0	16.0	128.0	64.0	51.0	12.0
75		185.0	93.0	74.0	19.0	161.0	81.0	65.0	15.0
100		246.0	123.0	98.0	25.0	211.0	106.0	85.0	20.0
125		310.0	155.0	124.0	31.0	264.0	132.0	106.0	25.0
150		360.0	180.0	144.0	37.0		158.0	127.0	30.0
200		480.0	240.0	192.0	48.0		210.0	168.0	40.0

These values of full-load current are in accordance with the National Electrical Code, and are motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torque may require more running current, in which case, the nameplate current rating should be used.

For full-load currents of 208- and 200-volt motors, increase the corresponding 220-volt motor full-load current by 6 and 10 percent, respectively.

† For 90 and 80 percent power factor the above figures should be multiplied by 1.1 and 1.25, respectively.

2. Use the table below to determine the wire size capable of carrying the total current.

ALLOWABLE CURRENT CAPACITIES OF CONDUCTORS, IN AMPERES, FOR NOT MORE THAN THREE CONDUCTORS IN A RACEWAY OR CABLE

A	B (Note 2)	C	D	E	F	G
Size AWG or MCM	Rubber types R, RW, RU, RUW (14-2) Type RH-RW (Note 1) Thermoplastic types T, TW	Rubber type, RH type RH-RW (Note 1) type RHW	Paper Thermoplastic asbestos type TA Var-Cam type V Asbestos Var-Cam type AVB MI Cable	Asbestos varnished cambric types AVA, AVL	Impregnated asbestos types AI (14-8) AIA	Asbestos types A (14-8) AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340

Note 1: If type RH-RW rubber-insulated wire is used in wet locations the allowable current carrying capacities will be that of column C, and if used in dry locations, the current carrying capacities will be that of column D.

Note 2: Insulation type and description.

Type	Description
R	code-grade rubber compound
RW	moisture-resistant rubber compound
RU	latex-rubber compound
RUW	latex-rubber, moisture-resistant compound
RH-RW	heat- and moisture-resistant rubber compound
RH	heat-resistant rubber compound
RHW	heat- and moisture resistant compound
T	thermoplastic-covered for dry locations
TA	thermoplastic- and asbestos-covered for switchboard wiring
TW	thermoplastic-covered for moist locations
MI	mineral-insulated, copper-sheathed for general use and special high-temperature locations
A	non-impregnated, all-asbestos, w/o asbestos outer braid
AA	non-impregnated, all-asbestos, with asbestos outer braid
AI	impregnated, all-asbestos, w/o asbestos outer braid
AIA	impregnated, all-asbestos, with asbestos outer braid
AVA	impregnated-asbestos and varnished-cambric with asbestos braid
AVB	impregnated-asbestos and varnished-cambric, flame-resistant cotton braid
AVL	impregnated-asbestos and varnished-cambric, outer asbestos braid, lead sheathed
V	varnished cambric

If the wire size determined from the table on page 18 is not available, use parallel runs of smaller wires or use the next larger size. Substitute sizes based on the current–carrying capacities of the wires are listed in the table below. The wire substitutions in the table should not produce excessive voltage drops along the distribution line. However, operators must monitor the voltage at the receiving end to ensure the size substituted carries the current efficiently.

SUBSTITUTE WIRE SIZES

WIRE SIZE	CURRENT CARRYING CAPACITY (AMPS)	NUMBER AND SIZE OF WIRES THAT MAY BE SUBSTITUTED FOR A SINGLE WIRE OF THE SIZE SHOWN IN THE FIRST COLUMN				
		2	3	4	5	6
1,000,000	455	300,000	000	0	2	3
900,000	435	300,000	00	1	2	3
800,000	410	250,000	00	1	2	4
750,000	400	250,000	00	1	3	4
700,000	385	0000	00	1	3	4
600,000	355	0000	0	2	3	4
500,000	320	000	1	3	4	6
100,000	280	00	2	4	—	6
300,000	240	0	3	4	6	8
250,000	215	1	3	6	—	8
0000	195	1	—	6	8	—
000	165	2	6	—	8	10
00	145	3	6	8	10	—
0	125	4	6	8	10	—
1	110	6	8	10	—	12
2	95	6	8	10	12	—
3	80	8	10	12	—	14
4	70	8	10	12	14	—
6	55	10	12	14	—	—
8	40	12	14	—	—	—
10	30	14	—	—	—	—

3. Use the table below to determine the total resistance of the cable when it is connected between the generator set and the load.

PHYSICAL AND ELECTRICAL PROPERTIES OF CONDUCTORS

STANDARD RUBBER CONDUCTOR		I.P.C.E.A. CLASS B STRANDING	AT 77°F (25°C)	
SIZE AWG	CIRCULAR MILS	NO. OF WIRES	BARE COPPER	TINNED COPPER
18	1,624	7	6.64	7.05
16	2,583	7	4.18	4.43
14	4,107	7	2.63	2.69
12	6,530	7	1.65	1.72
10	10,380	7	1.04	1.08
9	13,090	7	.824	.856
8	16,510	7	.654	.679
7	20,820	7	.519	.538
6	26,250	7	.410	.427
5	33,100	7	.326	.339
4	41,740	7	.259	.269
3	52,640	7	.205	.213
2	66,370	7	.162	.169
1	83,690	19	.129	.134
0(1/0)	105,500	19	.102	.106
00(2/0)	133,100	19	.0811	.0842
000(3/0)	167,800	19	.0642	.0668
0000(4/0)	211,600	19	.0509	.0525

Ampacity (amperes plus capacity) affects the size of wire required for a distribution cable. Ampacity is the current-carrying capacity of a cable or wire expressed in amperes. If the ampacity load is great and the wire length from the generator set to the load is short, ampacity considerations will require a larger wire size than the size normally required. When power requirements are low and the length of the line is long, the voltage drop criteria will require a larger wire size than the size normally required. The criteria resulting in the larger size wire govern the design of the distribution system.

NOTE: When a cable is installed overhead, use a minimum size of Number (No) 8 American wire gage. An overhead cable must meet the voltage-drop requirement and be strong enough to support its own weight plus any additional weight caused by fallen branches, ice, or snow.

BALANCING THE LOAD

The final task before selecting generator sets for a field unit is to balance the load among the phases. When balancing a load, the operator must ensure each phase carries an equal share of the load.

Loads may be connected between a power carrying conductor (live wire) and a ground (neutral) wire, or they may be connected between several live wires. When an operator connects a load between a live wire and a ground wire, any unbalanced current (power) in the line conductors is supplied through the ground wire. A load connected between two or more live wires is distributed equally among the live wires.

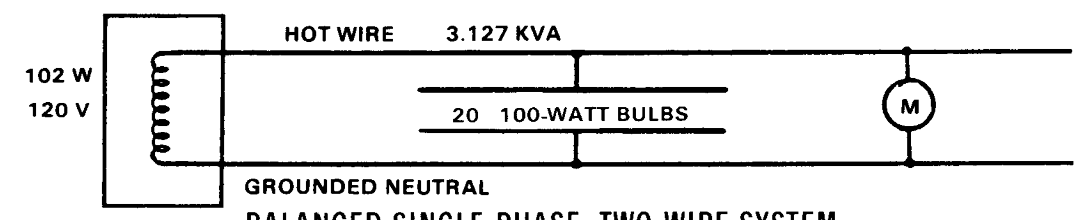
An installation fed by a three-phase, four–wire generator set can have a single-phase load attached to each of the three phases. Regardless of the number of loads supplied or how the loads are arranged, the generator supplies the total load on each phase. The generator attempts to supply the power required to satisfy the load in each phase. The power must be balanced so that each phase receives an equal amount of current from the generator set. The operator can ensure the loads are balanced by connecting the loads so that each phase receives an equal load.

An unbalanced load has two adverse effects:

- Unbalancing causes high voltage on the lightly loaded phase and low voltage on the other phase or other two phases. This causes poor voltage regulation throughout the system.
- A load that is unbalanced for a long time damages the generating equipment.

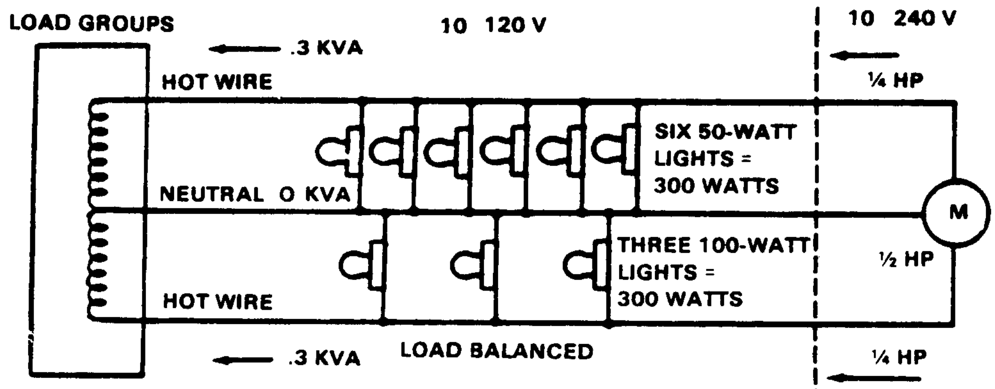
Single-Phase Systems

A single-phase, two-wire, 120–volt system cannot be unbalanced because the two wires are connected to one load. This basic load-carrying circuit is connected so that one–half of the total load is supplied by one live wire, and the other one–half of the load is supplied by the other live wire.



BALANCED SINGLE-PHASE, TWO-WIRE SYSTEM

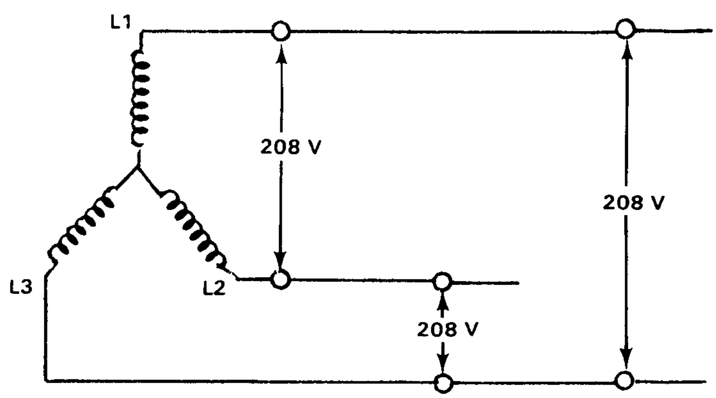
A single-phase, three–wire, 120/240–volt system has two live wires and one ground wire. It can supply power for two single–phase, 120–volt loads and one single-phase, 208/220-volt load group.



BALANCED SINGLE-PHASE, THREE-WIRE SYSTEM

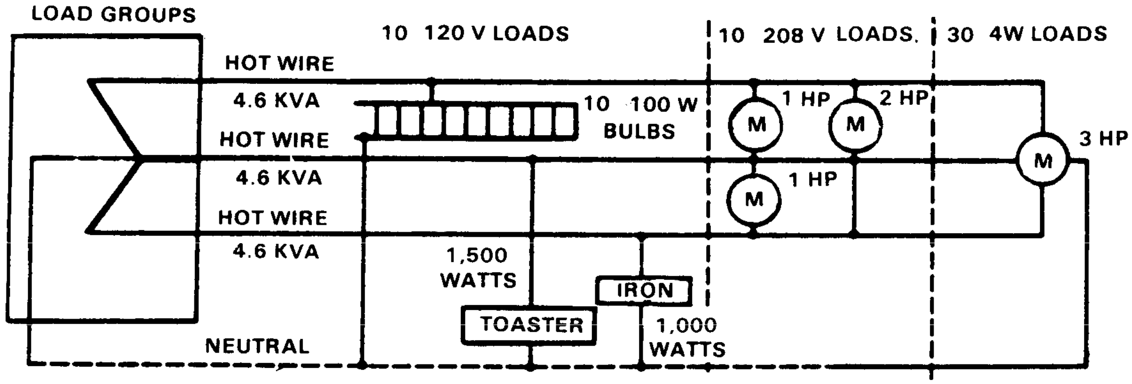
Three-Phase Systems

A three-phase, three-wire, 208-volt system has three live wires. It can supply three single-phase, 208–volt loads or one three–phase, 208-volt load. Divide the total load equally between the three live wires for a single-phase connection.



BALANCED THREE-PHASE, THREE-WIRE SYSTEM

A three-phase, four-wire, 120/208-volt system (figure on page 23) has three live wires and one ground wire. This system can supply power for a single-phase, 120-volt load; a three-phase, 208-volt load; and a single–phase, 208-volt load.



BALANCED THREE-PHASE, FOUR-WIRE SYSTEM

When the total load is balanced, the operator marks the voltage and number of phases needed on a site diagram. The voltage and phase requirements are marked plainly on most AC and DC motors.

SELECTING THE GENERATOR

After the distribution system is designed and the load is balanced, the operator can select the generating equipment to produce the power needed for the field unit. The following factors govern the selection process:

- Electrical loads to be supplied.
- Kilowatt rating requirements.
- Operating voltages required.
- Number of phases required.
- Frequency requirements.

In addition to these factors, the availability of fuels, the expected life of the field unit, the availability of skilled maintenance personnel, and the probable load deviation must be considered when selecting generating equipment for a field unit.

The electrical systems at most military field units supply power day and night for various lighting, heating, and power equipment. The annual load factor of a well–operated, active field unit is 50 percent or more of the capacity of the generator sets. The annual load has a power factor of 80 percent or more of the average power factor. Therefore, all of the above criteria must be considered when selecting generating equipment.

The layout of the field unit must be considered when selecting generating equipment. For example, if the load is more than a few hundred feet from the generator set, a high-voltage distribution system may be needed. If the power plant serves a primary distribution system, the generator set must be rated at the distribution system's voltage. This eliminates the need for a transformer at the sending end. Also, the number of phases required by the load may differ from that of the generators on hand. Because most loads can be divided and balanced between phases, most medium- and large-sized generator sets are designed for three-phase operation.

Most electrical loads in the United States require a frequency of 60 cycles. Although equipment operators try to maintain a constant frequency throughout the electrical system, deviations sometimes occur. Most electrical equipment operates satisfactorily when the frequency drifts approximately 5 cycles above or below 60 cycles. Equipment such as teletypewriters and electric clocks are sensitive to frequency changes. The operator must consider frequency drift when selecting generator sets that supply power to equipment sensitive to frequency changes.

Operators must select generator sets that are the proper size and type for the field unit's needs. If a central generating station is needed but there is not enough time to build one, the operator must install a generator set at each work site that requires power. The size of the generator set selected for each work site will depend on the needs of the site. For example, the electrical load at a headquarters building that consists of lights and single–phase motors can be supplied by a small, single-phase generator set. A maintenance shop that uses large amounts of single-phase and three-phase power requires a three-phase generator set.

The choice of generator set must be coordinated with the maintenance and supply facilities at the field unit. Maintenance skills and the necessary tools and spare parts required for the selected generator must be available at the field unit.

Power and Voltage Requirements

The power and voltage requirements of the load determine the size of the generator set used. For example, a two–wire, 120-volt generator set with an output rating of 1.5 kw produces enough electricity for equipment rated at 120 volts, single-phase, with a combined power load of less than 1.5 kw (1,500 watts). A 5-kw, AC generator set produces enough electricity for equipment requiring between 1.5 kw and 4.5 kw.

If motors are part of the load, the capacity of the generator set must be increased above the capacity normally required. The increased capacity is needed to compensate for reduced terminal voltage when large motors are started and when frequency surges occur during motor acceleration. These power drains may adversely affect the performance of electronic systems and other equipment fed from the same generator set. Also, motors already running may stall when large motors are started. Operators can avoid these and similar problems by removing the existing load when starting a large motor. Place the small loads back on the generator set after the large motor has reached its required speed.

Some single-phase loads contain equipment rated at both 115 and 230 volts. These loads require a generator set with a single–phase, three-wire, 120/240-volt output.

The size of the load is a primary consideration when selecting a generator set. Determine the capacity needed to support the load before selecting a generator set. Sets with capacities ranging from 0.5 kw to 500 kw are available.

Selection Guides

Use the following guides to select a generator set:

- Single-phase equipment provides power for small lighting, AC and DC motors, special equipment such as radial (arc) electric welders, and some furnace loads. Either a two- or a three-wire system may be used, depending on the size of load and the area serviced.

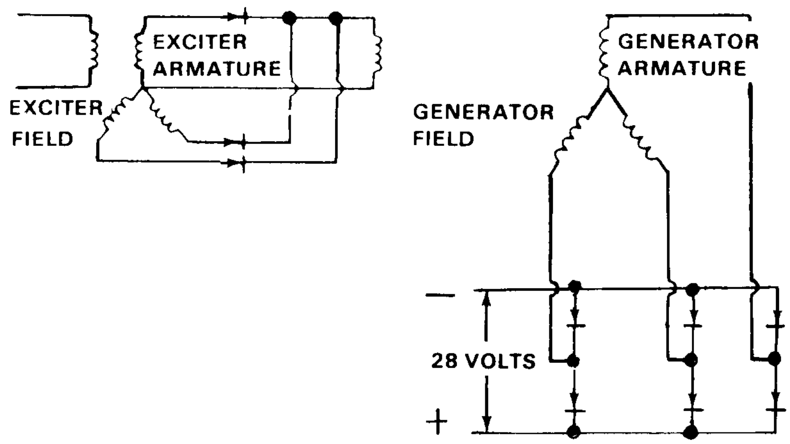
- Three-phase equipment provides power for almost everything except small loads. The generation and transmission lines usually are three-wire systems, but the distribution circuits may be three- or four-wire. When single-phase power is obtained from three-phase circuits, operators must balance each phase at the generator set.

- To determine the voltage required for a generator set, consider the distribution circuits; the size, character, and distribution of the load; the length, capacity, and type of transmission lines; and the size, location, and connection of the generator sets.

- Lighting is universally rated at 120 volts in the United States. The voltage required for lighting can be obtained from a single-phase, two-wire, 120/240-volt circuit or a three-phase, four-wire, 120/208–volt circuit. The general use of combined lighting and small motor circuits increases the use of 120/208 volts for general power application.

- Small motors of less than 5 horsepower are supplied by DC or single–phase AC systems at 120 volts. Large three-phase motors, 5 horse–power or more, usually operate satisfactorily between 200 and 240 volts.

- The DC generator sets are used for specific tasks, and selection is based on the task to be performed. Battery charging is the main use of DC generators. A practical wiring diagram of a two–wire, DC generator set is shown in the figure on page 26.



TYPICAL WIRING DIAGRAM OF A TWO-WIRE, DC GENERATOR SET

- The use of a single generator set is the least desirable method for obtaining continuous electricity. A single generator set is used when the set is isolated from the distribution system and when equipment failure will not seriously affect the field unit's mission. Sometimes a single generator set is used to power extremely large loads that cannot be tied into a limited distribution system.

Generator sets have gasoline, diesel, or gas turbine engines. Fuel is a major factor to consider when selecting a generator set. For example, fuel availability may limit the choice of engines in advanced or isolated areas. Use the following guides to select the type of engine for a generator set:

- Most gasoline engine–driven generator sets are similar to small automotive engines. Therefore, maintenance problems on these sets may be easier to correct than maintenance problems on other, less known, engines.

- Diesel engine-driven generator sets usually operate for longer periods and under greater strains than the gasoline engine–driven generator sets. Also, diesel engines usually require less maintenance than gasoline engines because of their construction and lack of an ignition system.

- Gas turbine engine-driven generator sets consume a lot of fuel, but they offer some advantages. Because these generators have a minimal warm-up time, a load can be applied almost immediately. Also, these sets are not limited to a specific fuel--they have multifuel capability.

Load Classification Requirements

The operator must properly match the load to the generator set at the field unit. Loads are classified as inductive or resistive. The load classification partly determines the amount of load a generator can support. The generator set rating information is in amperes, kilovolt-amperes, kilowatts, power factors, or all of these. If the only data available on a generator set are the kilovolt-amperes, power factor, and voltage output rating, the operator must determine the load classification.

A generator can support its kilovolt-amperes rating if the major portion of a load is inductive. For example, a model MEP-017A generator set rated at 6.25 kilovolt-amperes can support a 6.25 kilovolt-amperes inductive load.

A generator with a load that is entirely resistive may easily be overloaded because it can support only 80 percent of its kilovolt-amperes rating. For example, a model MEP-017A generator set rated at 6.25 kilovolt-amperes can support only a 5-kw load (6.25 x 0.80 = 5). A generator set with a rating of 0.8 power factor cannot support that rating in kilovolt-amperes if the load is purely resistive (a power factor of 1.0). If the ampere rating is known, calculate the total amperes required to support the load but do not exceed the rating of the generator set.

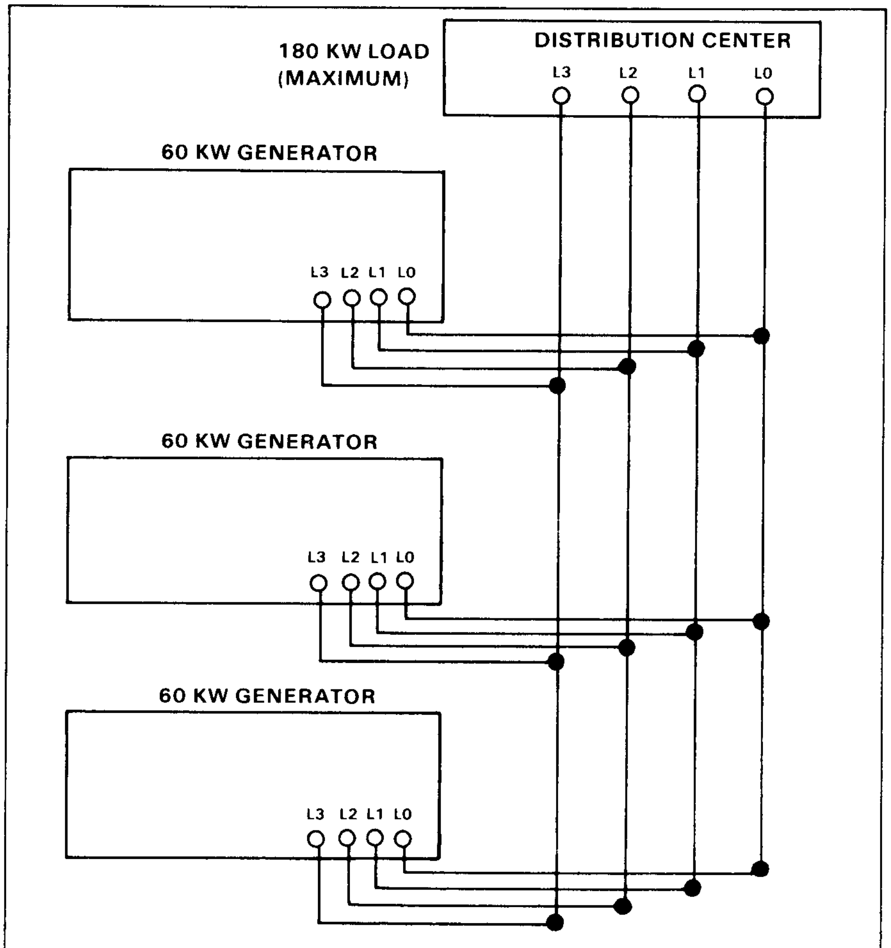
Many generator sets are designed so the operator can select one of several voltages. The ampere rating changes as the voltage output changes. Thus, a model MEP-018A, 5-kw generator set can supply any of the following voltages and amperes:

Phase	Voltage	Amperes
Single	120	104
Single	240	52
Three	120	34.7 (per phase)
Three	208	17.3 (per phase)

Generator set rating information is on the alternator data plate and in the tabulated data section of the technical manual for each generator set.

PARALLELING THE GENERATOR SETS

Sometimes a field unit with only small- and medium-sized generator sets needs a large quantity of power. The operator can accomplish this by connecting and operating two or more generator sets in parallel. When generator sets are connected in this way, their combined kilowatt rating is equal to the sum of the kilowatt ratings for each set. Parallel connected generator sets are shown in the figure below.



PARALLEL CONNECTED GENERATOR SETS

The two main reasons for connecting generator sets in parallel are to provide continuous power and to allow shutdown time for servicing equipment. Installations that require continuous power, such as surgical hospitals, use parallel connected generator sets to avoid power outages. Generator sets are shut down and serviced periodically. When they are connected in parallel, one set can be shut down and serviced while the others continue to operate. Thus, an installation can receive continuous power with no time lost for maintenance and repair.

Operators must synchronize the parallel generator sets before they are connected to the load. Complete the following steps in sequence to synchronize a base set and an incoming set:

1. Close the main circuit breaker on the base set.

2. Ensure the voltmeter indicates the frequency required for the load.

During the synchronizing process, the base (operating) generator set may be connected to the load and operating or it may be disconnected from the load and operating. After steps 1 and 2 are completed, the incoming generator set may be synchronized with the base unit.

3. Open the circuit breaker on the incoming generator set.

4. Ensure the voltage output and the frequency output of the incoming generator set are the same as those of the base set.

5. Place the paralleling switch on the control panels of the base and incoming generator sets in the on position. When the paralleling switches are on, the two paralleling lamps on the control panel of the incoming set will begin to blink on and off. Both lights must become bright and then dark at the same time. If they do not, the generator sets are connected incorrectly.

NOTE: Turn off all power before reconnecting the generator sets.

The lamps must go on and off together. If the base set is under a power load, observe the kilowatt meter (percent of power meter) on the base set. Then go back to the incoming set and observe the paralleling lamps. Adjust the throttle (on utility sets) or the frequency adjust rheostat (on precise sets) until the lamps go on and off at 3- to 5–second intervals. When the lights are completely dark, close the main circuit breaker on the incoming set. Adjust the frequency rheostat of the incoming set until the kilowatt meter indicates one-half of the power of the base set. Adjust the voltage rheostats on both sets, if necessary, to eliminate crosscurrents.

If the current meter on either set indicates excessive current and the voltage rheostat will not balance the current, do not operate the generators in parallel. Refer to the next higher level of maintenance.

When the synchronizing lamps blink in unison, the two sets are operating in parallel as one base unit. Complete steps 3 through 5 for each additional incoming set. The percent of power meter on the third set should indicate one–third of the load on the base set.

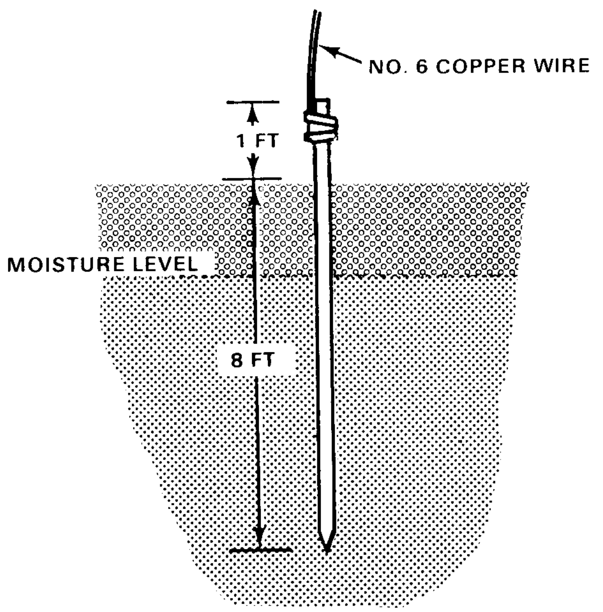
6. After all the generator sets are operating in parallel, divide the load equally among them. To do this, adjust the voltage and frequency outputs of each set. This step completes the paralleling process.

GROUNDING SYSTEMS

Electric power generating equipment must be grounded as a safety precaution. Stray electric current within the generator set or in the distribution system can injure or kill the operator and damage the equipment. Portable field power generating equipment may be grounded with a grounding rod, grounding pipe, or a grounding plate.

Grounding Rod

The standard grounding rod used by military units is a 5/8-inch copper rod with three, 3–foot sections. To install a grounding rod, drive it at least 8 feet into the soil. The rod must be buried below the moisture level. If this cannot be done, replace the grounding rod with an 8–foot electrode. Bury the electrode in a horizontal trench that is at least 2 1/2 feet deep. The electrode must be placed below the moisture level, as shown in the figure below.

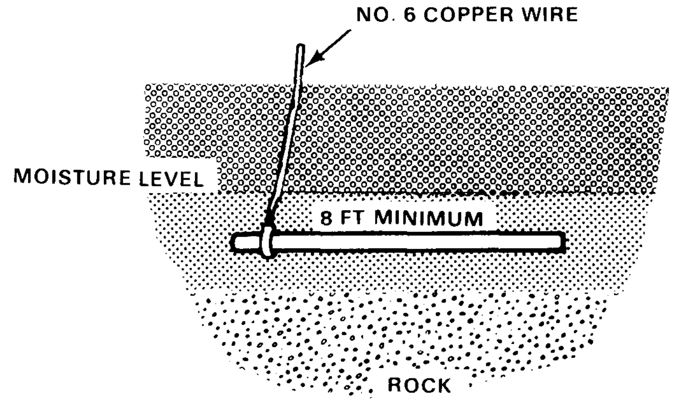


TYPICAL ROD OR PIPE GROUND ELECTRODE

If one grounding rod does not produce a good grounding system, the operator can form a network with three or more rods. Install the rods about 6 feet apart. If three rods form the network, place them in a straight line or in a triangular pattern. Install more than three rods in a straight line. Connect the grounding cable from the generator set to each grounding rod so they are in series.

Grounding Pipe

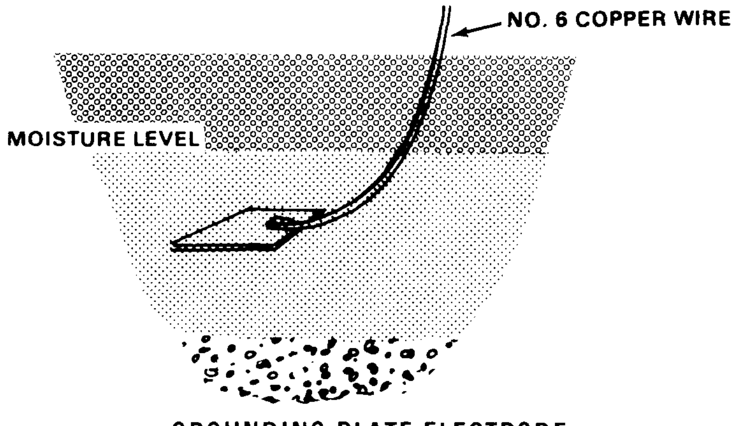
Use a clean, metallic pipe of 3/4-inch trade size or larger to make a grounding pipe. Pipes made of iron or steel must be galvanized or coated for corrosion protection. Drive the pipe at least 8 feet into the soil. If this cannot be done, replace the pipe with an 8-foot long electrode. Bury the electrode in a horizontal trench that is at least 2 1/2 feet deep. The pipe must be placed below the moisture level.



GROUNDING PIPE

Grounding Plate

A buried grounding plate (plate electrode) may be used as a ground. The plate must be at least 36 inches in width and length (9 square feet). An iron or steel plate may be substituted for a plate electrode if it is at least l/4-inch thick and coated for corrosion protection. Grounding plates must be buried below the moisture level.



GROUNDING PLATE ELECTRODE

Attach the grounding system with No 6 American wire gage or a larger cable. Connect one end of the cable to the grounding terminal of the generator set. Tighten the nut securely, as described in the appropriate technical manual. Connect the other end of the cable to the grounding electrode with a special grounding clamp.

Soil Conditions

Contact with the earth does not guarantee a good grounding system. The soil type, moisture content, and soil temperature affect the efficiency of the grounding system. The characteristics of four types of soils are described in the table below.

SOIL CHARACTERISTICS

TYPE OF SOIL	QUALITY OF GROUND
Fine soil granules with high moisture content	Very good
Clay, loam, shale	Good
Mixed (clay, loam, shale mixed with gravel or sand)	Poor
Gravel, sand, stone	Very poor

Soil is divided into two distinct layers. Topsoil, the first layer, usually ranges from 1 to 6 inches deep. Because it is often dry and loosely packed, topsoil is not a good electrical conductor. Subsoil, the second layer, usually is tightly packed, retains moisture, and provides the best electrical ground. Wet soil passes electric current better than dry soil and allows the grounding system to work efficiently.

A chemical solution is used on soils to improve a poor or very poor grounding system. To make this solution, mix 5 pounds of sodium chloride (common table salt) with 5 gallons of water (1 pound of salt to 1 gallon of water). Dig a hole that is about 1 foot deep and 3 feet wide. Pour the solution into the hole and allow it to seep into the soil. Install the grounding rod in the hole, connect the grounding strap, and fill the hole with soil. Keep the soil around the rod moist at all times.

Frozen soil is a poor conductor of electric current. When the soil temperature drops below 32 degrees Fahrenheit (32°F) or 0° Celsius (C) and the soil moisture freezes, the effectiveness of the grounding system decreases. To compensate for low soil temperatures, locate the grounding system near a source of heat, such as a generator set or vehicle exhaust. When it is difficult to install an effective grounding system because the soil is frozen, connect the grounding strap to something that is already grounded. The grounding strap can be attached to a metal building or an underground pipe. Attach the strap with a grounding clamp if possible; if not, attach it with a bolt.

Another alternative is to drive several grounding stakes into the soil at different locations to form a grounding network. Drive the stakes to the greatest depth possible. If necessary, drill, dig, or blast a hole in the soil, and use the salt solution described previously. A temporary ground may be made by driving a spike deep into a large tree.

The extremely dry and loosely packed desert soils provide a very poor electrical grounding system. Increase the efficiency of whichever grounding system is used in desert soils with the chemical solution described previously. Keep the soil around the grounding system moist at all times. Locate the equipment near an oasis or subterranean water if possible.

In the rocky terrain typical of mountainous areas, site selection is the key to providing a good grounding system. Try to locate the equipment near a streambed.

Use a slip hammer to drive a grounding rod into packed, rocky, or frozen soil. This tool can be made locally (garrison) and used to install and remove a grounding rod (figure on page 34). Order a slip hammer through normal supply channels as a driver/puller, national stock number (NSN) 5120-01-013-1676.

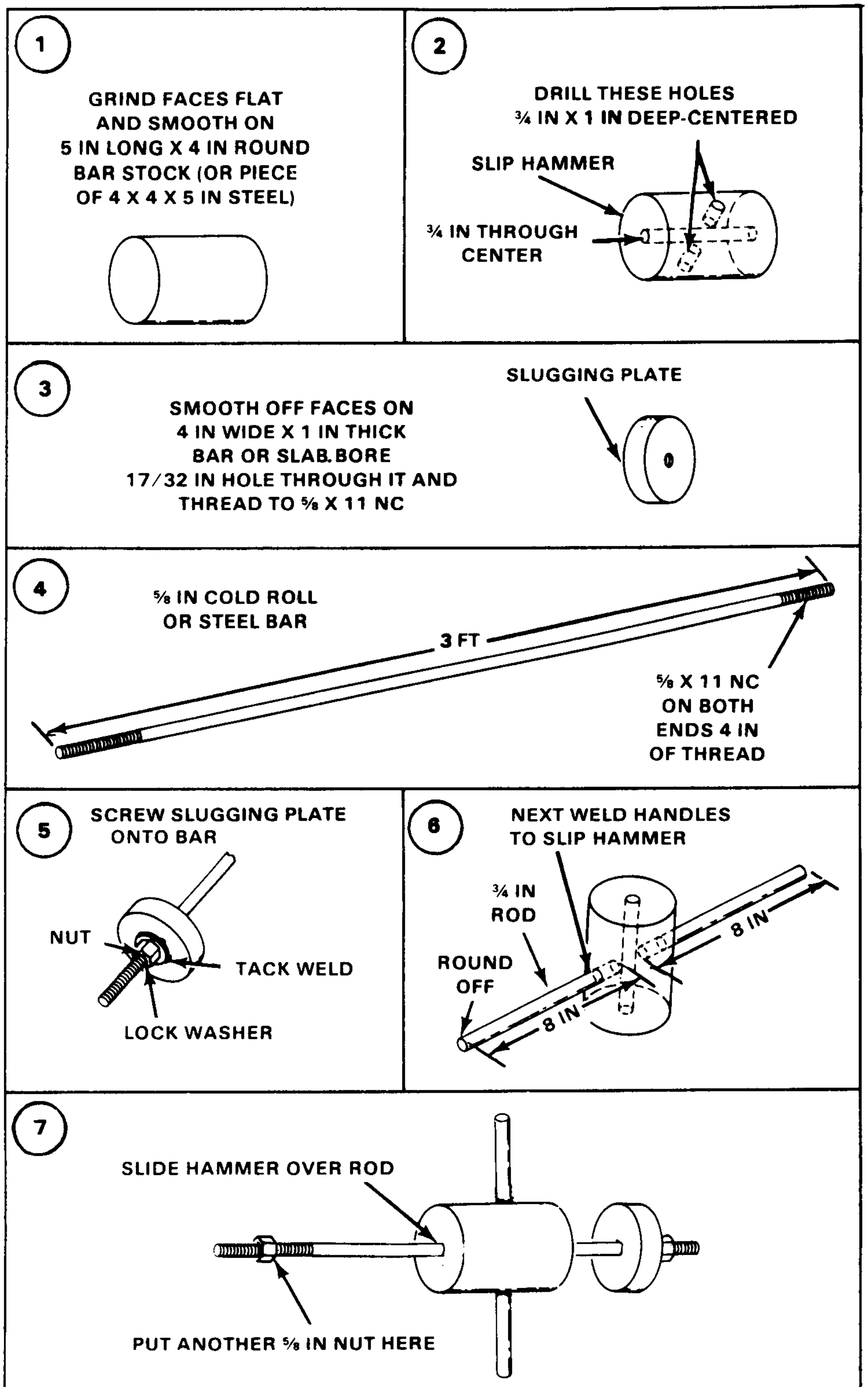
Soils in tropical areas, such as jungles or rain forests, provide good electrical ground for the grounding rod assembly issued with the generator set. Grounding rods are easily installed in these moist soils. The fast buildup of corrosion is a problem in the tropics. To ensure a good electrical path, apply waterproof tape at the connection of the grounding strap and keep the grounding rod clean and dry.

Perform the following checks and services to establish a good grounding system:

Grounding rods.
Remove paint, oil, and grease. Keep the rods clean. Ensure the rods are as straight as possible. Keep the points sharp enough to penetrate the soil.

Grounding straps.
Remove paint, oil, and grease. Keep the straps clean. Ensure the straps and cable are the proper length.

Connections.
Remove paint, corrosion, oil, and grease. Use the proper clamps and connections for the grounding system selected. Tighten the terminal screw and the grounding clamp screws properly.



MAKING A SLIP HAMMER

SELECTING THE GENERATOR SITE

The location of the generator set affects the efficiency of the power system. The individual demands for electric power and the area to be serviced govern the site selected. Generator sets usually are located near the large demands.

The operator must determine where the large demands are located. To do this, the operator studies the map on which the individual demands are plotted. If additional sets are needed for parallel operations, plot them on the map. All the power demands must be plotted on the map before the site is selected and prepared for the generator set.

Place the generator sets near the largest loads. This practice reduces the size of wire cable required, minimizes the line voltage loss, and provides voltage control at the demand end of the line.

Operators should provide shelter for the generator set. Although the equipment is weather-resistant, it needs protection from inclement weather and enemy fire. A revetment type of shelter, described on page 37, provides protection from weather and enemy fire, and it also controls noise levels. Revetment shelters are used for air–cooled generator sets that produce from 0.5 kw through 10 kw of electricity. The shelter should provide ventilation to maintain a reasonable temperature around the generator and allow heated air and exhaust fumes to escape. If the generator set operates in a closed structure, the exhaust gases must be piped outside.

WARNING

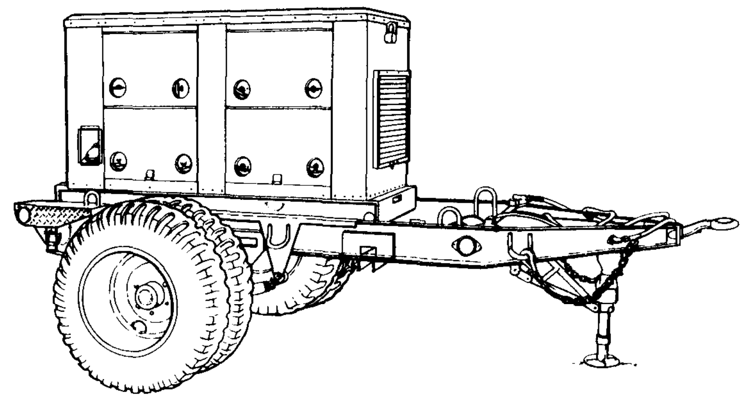
> Never operate an air–cooled, gasoline engine–driven generator set inside a closed building unless forced ventilation can remove the engine heat and exhaust gases outside. Exhaust gases contain carbon monoxide--a poisonous, odorless, and colorless gas.

The pipe used to remove exhaust gases must be installed properly. The pipe should be as short as possible and have no more than one 90-degree bend. Keep combustible materials 6 inches or more from the exhaust pipe. Wrap the pipe with insulation if personnel may touch it accidentally.

Use the following guides to select a site for power generating equipment:

- Provide enough clearance around the generator set to perform maintenance procedures.
- Locate generator sets away from areas where noise may be a problem. Most mobile generator sets produce high noise levels.

- Mount the generator set in an area that is clean, level, dry, well ventilated, and well drained. Use planks, timbers, logs, ammunition boxes, or other material to prevent the skids or frame from sinking into soft earth. Keep the set level, preferably within 5 degrees, for proper lubrication. Never tilt the set more than 15 degrees in any direction. Cargo trucks sometimes are used for mounting generator sets, but more often they are mounted on two–wheeled trailers for greater maneuverability and ease of maintenance. When the set is mounted on a trailer, it is called a power unit.



TRAILER MOUNTED GENERATOR SET

- Mount the generator set on a surface that can support the weight of the equipment.

- Provide a Supply of clean fuel that is sufficient for all requirements planned for the life of the installation. For a long–term installation, consider placing the fuel tanks underground.

- Locate the auxiliary fuel tanks for generator sets that produce less than 10 kw as near the shelter as possible. The bottoms of the tanks must be less than 4 feet below the fuel pump on the installed generator set. The fuel tanks for sets producing 15 kw or more must be located less than 12 feet below the fuel transfer pumps. Connect the fuel line between the auxiliary fuel tank and the fuel selector valve. Ensure no dirt or moisture gets into the fuel lines.

- Enclose auxiliary fuel supply tanks that are above ground with engineer tape to rope off the area. Place NO SMOKING signs at each entrance to the fuel supply area, at least 50 feet from fuel supply and the generator set. If possible, construct a shelter to protect the auxiliary fuel supply from direct sun rays and rain. Install a fire point that includes a fire extinguisher (monobromotric–fluoromethane type), shovel, and pickax.

- Provide adequate shelter for generators that will be in service at one location for a long period of time. Use noncombustible material for the shelter if possible. Allow a clearance of 4 to 6 feet if combustible materials are used. A lean-to, shack, or shed can shelter generating equipment adequately.

- Provide a suitable foundation so the generator set can be bolted to the floor. This will eliminate unnecessary vibrations. Do not use the portable, totally enclosed, and winterized type of generator set in a permanent, indoor installation.

CONSTRUCTING A REVETMENT

Air-cooled, engine-driven generator sets are designed to operate in the open with unrestricted ventilation. However, a revetment may be needed to protect the equipment from extreme weather and enemy attack (figure on page 38).

NOTE: Use revetments only for air-cooled, engine–driven generator sets.

The revetment described in this section is designed to shelter one generator set. Install only one generator set within each revetment. Also, do not place other heat generating equipment in a revetment with a generator set. Anything inside a revetment that creates heat will adversely affect the cooling of the set.

Dimensions

The minimum allowable inside dimensions for a revetment for generator sets rated from 1.5 kw through 10 kw are 7.5 feet long, 5.5 feet wide, and 4.0 feet high. The height includes l.O-foot openings around the top of walls that are 3.0 feet high. The entrance into the revetment should be 2.0 feet wide. The height of the sill at the bottom of the entrance should be 1.0 foot or less.

A revetment with these dimensions is also suitable for generator sets that produce 0.5 kw of electricity. However, to economize, the width and length can be reduced to 4.0 feet and 5.0 feet, respectively.

The above minimum dimensions are based only on engine cooling and ventilation considerations. They allow the minimum space required for servicing and maintaining equipment.

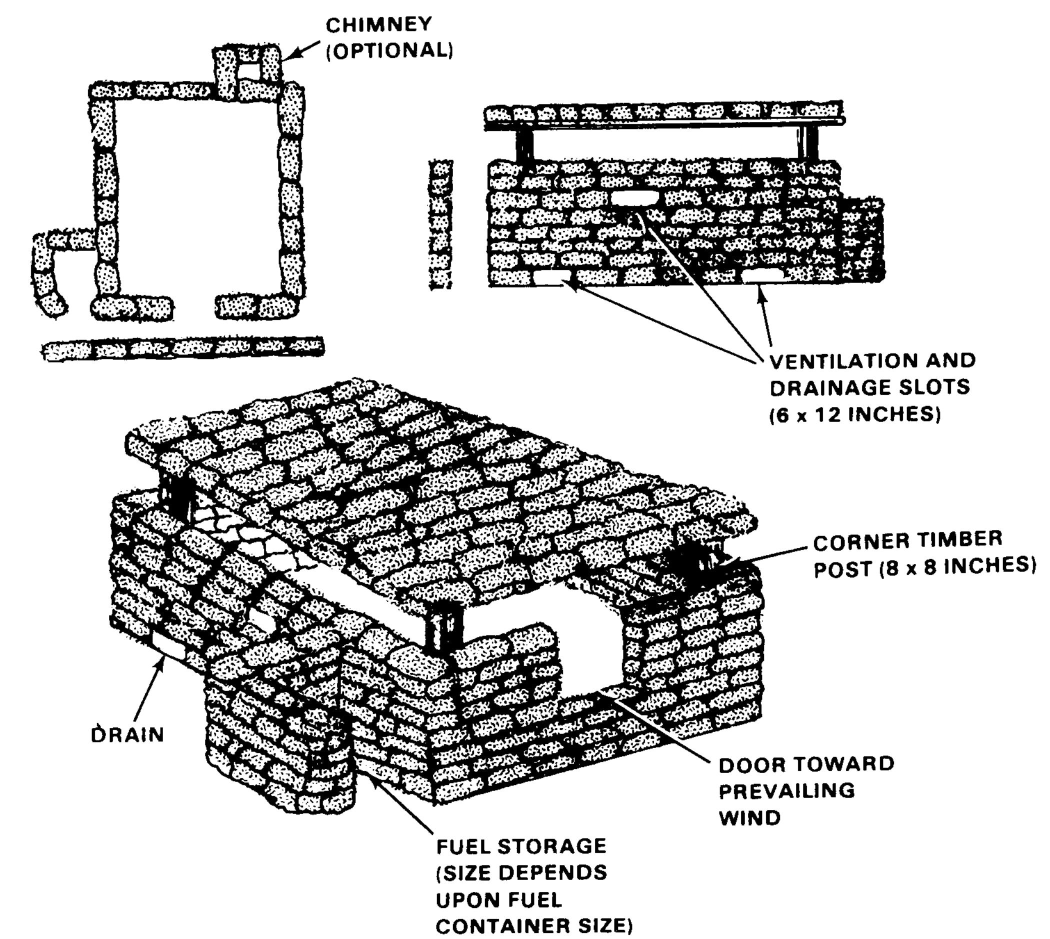
Foundation and Drainage

Generator sets require an adequate foundation. If the generator set is attached to a shipping pallet, the pallet provides an adequate foundation. If the set is not attached to a pallet, use planks, timbers, logs, ammunition boxes, or other materials to prevent the skids of the frame from sinking into soft earth. The foundation must be less than 6 inches high.

A drainage system is required to ensure runoff flows away from the generator set and out of the revetment. Locate all drain holes at the inside ground level. Install a sump and drainage trench for each drain hole if the water does not drain away from the revetment naturally. Locate the sump and drainage trench outside the revetment.

Wall Construction

The walls of the revetment may be constructed with sandbags, ammunition boxes filled with sand or dirt, or any other materials.



REVETMENT CONSTRUCTION

Roof Construction

The roof can be supported by any means possible, but it must be at least 1.0 foot above the wall of the revetment. Allow as much open space between the top of the walls and the roof as possible for ventilation. Roof construction usually consists of two pieces of lumber (4 inches by 4 inches) or logs (4 inches in diameter), about 10 feet long, and enough cross pieces of lumber, logs, or steel planking to cover the entire roof. The cross pieces should be about 8 feet long. If the above materials are not readily available, use any available material.

The amount and type of protection desired determines the thickness of the roof. When adding roof protection, be sure the roof can support the additional weight.

Miscellaneous Construction

Construct a compartment outside the revetment for fuel storage, as shown in the figure on page 38. The size of this storage area depends on the size of the fuel containers. The fuel supply is stored outside the revetment to minimize the hazards associated with fuels at high temperatures. Air temperatures within the revetment increase considerably above the ambient temperature outside when the generator set operates. Some generators are equipped with integral fuel tanks. Do not use the integral fuel tanks in a revetment because of the hazards associated with fuels at high temperatures.

The exhaust from the engine may or may not be ducted out of the revetment. This decision is left to the commander. Install a flexible pipe (chimney) similar to the one shown in the figure at the top of page 60 if the exhaust is ducted outside. If a flexible pipe is not available, use a piece of exhaust pipe or similar material. The point where the exhaust discharges through the revetment wall depends on the type of generator set and exhaust pipe. The exhaust may or may not be discharged into an external exhaust chimney. However, a chimney is preferred because it helps duct the exhaust gases away from the revetment and reduces the noise level.

Construct a revetment doorway shield that is similar to a revetment wall (figure on page 38). The shield is a wall that prevents projectiles and fragments from entering directly into the revetment. The doorway shield must be 3.0 feet high and 7.5 feet long.

Alignment Instructions

When constructing the revetment, align the structure so that the door faces into the direction of the prevailing wind. Install the generator set so its long axis is parallel with the long axis of the revetment. Center the set within the revetment walls. Use the following information to orient the generator set:

ENGINE-DRIVEN GENERATOR SET ORIENTATION

Generator set Output (kw)	Orientation
1.5	Generator end toward the door.
3.0	Engine end toward the door.
4.0	Generator end toward the door.
10.0	Generator end toward the door.

Chapter 3

Set-Up, Installation, and Operation Procedures

Equipment operators must be able to set up and install an electric generator set in the field and determine locations for the fuel supply and maintenance facilities. This important function, if performed properly, helps ensure safe and efficient equipment performance throughout the field operation. The tasks required to set up and install an electric generator set and support facilities in the field are described in this chapter.

PRELIMINARY INSTRUCTIONS

An electric generator set may arrive in the field completely operational and ready for use. However, if the equipment was shipped from a supply or maintenance point, the fluids have been drained out of the set and it is not in an operational ready status. Several preliminary tasks are required to set up the equipment and support facilities for a field unit.

Inspect the Equipment

The equipment operator must carefully inspect all incoming equipment:

- Inspect the identification plate. Ensure the information on the plate matches the equipment.
- Inspect the generator set for damage. Document all damage on a DA Form 2404 (Equipment Inspection and Maintenance Worksheet). Submit the form to the next echelon of maintenance.
- Compare the equipment with the packing list to ensure all items shipped are present and serviceable.
- Inspect the entire unit carefully for loose and missing hardware. Tighten loose hardware and replace missing items.

- Turn the engine over by hand to ensure all moving parts in the engine and generator move freely.

Service the Equipment

Perform the following daily preventive maintenance services after the equipment is inspected:

- Remove all tags, tape, cloth, and barrier materials.

- Lubricate the generator set's engine according to the instructions in the current lubrication order.

- Correct as many of the deficiencies as you can. Report the rest to organizational maintenance.

Install the Fuel Supply

One of the equipment operator's most important tasks is to properly install the fuel supply and storage tanks required for the generator set. Gasoline, diesel fuel, or jet fuel (JP-4) may be used to power the generator set. Operators must consider the following factors when planning the installation arrangements for the fuel storage area:

- Planned duration of the field installation.
- Security requirements.
- Potential fire and safety hazards.
- Potential sources of contamination.

The length of time the field unit will be in operation partly determines how the fuel storage facilities are installed. For a long–term field unit, install the fuel tanks underground using proper fittings. Ensure the tanks comply with the manufacturer's instructions. Select a location that is convenient to the using equipment. Proper installation and a convenient location minimize the hazards of fuel contamination, vapor lock, and fire.

For a short-term field unit, locate the auxiliary tanks or drums above the ground. Place them as far from the using equipment as the auxiliary line allows. If a metal pipeline is used, locate the tanks about 25 feet from the generator set. Keep the auxiliary fuel line as straight as possible.

Maintain Security

Follow the unit's standing operating procedures.

Eliminate Potential Fire and Safety Hazards

Fire and safety are critical elements in the design of a fuel storage area. The following tips will help eliminate many fire and safety hazards:

- Clearly mark the entire fuel storage area with NO SMOKING and OPEN FLAME signs to indicate it is a hazardous area.
- Dig an open trench 4 feet wide and 6 inches deep around the area to contain any fuel leaks or spills. Pile the earth in a mound around the trench. Place crushed rock or sand inside the trench to absorb spilled fuel. Immediately cover any small spills with dry sand or earth.
- Prohibit trash burning within 200 feet of any fuel storage area.
- Do not place any electrical wires above or near the fuel tanks.
- Direct hot exhaust from operating engines away from the fuel supply.
- Bury or cover fuel lines leading away from fuel tanks to protect them from the sun and physical damage.
- Do not use a rubber hose for fuel delivery except as a temporary measure. To make the hose safe, attach or clamp a light, flexible copper wire to the end fittings of the hose. Twist a ground wire around the hose to prevent breakage and to provide a path for static electricity to flow to the ground. Attach one electrical grounding wire to the auxiliary tank and another to the generator set.
- Do not use a long, nonconductive hose for fuel delivery except as a temporary measure. Static electricity builds up when fuel flows through a long pipe or hose.
- Maintain adequate fire extinguishing equipment near the auxiliary fuel tank area and the generator set. The fire point must include a shovel, pickax, and a fire extinguisher. Include buckets of sand in the fire point if they are available.

Maintain the Fuel Supply

The operator must maintain a fuel supply adequate for all needs. The following tips will help ensure the proper fuel is on hand and is used for each task:

- Ensure the type and grade of fuel used in a generator match the specifications.

- Never mix different fuels. Label each storage tank clearly with the type and grade of fuel it contains. Ensure only that fuel is put in the tank.

- Clean a tank thoroughly before changing the grade and type of fuel stored in it. Drain all the old fuel out and remove the sediment and condensation. This procedure prevents improper operation or damage to the generator set.

- Ensure fuel does not spill on any engine parts when draining an engine-mounted fuel tank. Connect a flexible hose between the petcocks and the container if the fuel cannot drain directly into the container.

The fuel supply for an electric generator set must be free of contamination. The equipment operator can help ensure a pure fuel supply by identifying potential sources of contamination and planning around them. Locate the fuel storage area at least 50 feet from all work areas and equipment that does not require fuel. The storage area must be at least 50 feet from heavily traveled roads but be easily accessible by the fuel supply trucks. Locate the storage area so that any fuel leaks there flow away from the equipment, personnel work areas, and housing. A shelter or cover may be needed to protect the fuel from contamination.

Perform Before-Operation Checks and Services

Equipment operators must perform several checks and services before starting an electric generator set. The checks and services usually performed on all generator sets are described in this chapter. Refer to the manual issued with the set to ensure all checks and services required for a specific set are performed properly.

NOTE: Use the equipment manual to obtain the correct operating data.

- Check the fuel lines for leaks. Check the fuel level in the tank and refill it as needed. If winterization equipment is used, check the heater for fuel leaks. The heaters in some generator sets use diesel fuel from the main tank. Check the fuel level in the auxiliary tanks. Drain condensation from the tanks, and clean the fuel filters before operating the equipment.

- Inspect the plenum drain fitting before starting a gas turbine engine-driven generator set. Ensure it is clear and that no fuel has accumulated in the plenum chamber. Use only clean fuel. Drain the sediment from the filter into a small container and dispose of the sediment. Check the fuel control valves for proper positioning.

- Check the radiator coolant level; add coolant if necessary. Allow room for expansion when filling a cold radiator. If cold weather is anticipated; add antifreeze according to the instructions in the table below.

FREEZING POINTS, COMPOSITION, AND SPECIFIC GRAVITIES OF MILITARY ANTIFREEZE MATERIALS

LOWEST EXPECTED AMBIENT TEMP °F	PINTS OF INHIBITED GLYCOL PER GALLON OF COOLANT [1]	COMPOUND, ANTIFREEZE ARCTIC [2]	ETHYLENE GLYCOL COOLANT SOLUTION SPECIFIC GRAVITY AT 68°F [3]
+20	1¾	Issued full-strength	1.022
+10	2	and ready mixed	1.036
0	2¾	for 0° to -65°F.	1.047
-10	3¼	Temperatures for	1.055
-20	3¾	both initial instal-	1.062
-30	4	lation and replen-	1.067
-40	4¼	ishment of losses.	1.073
-50	Arctic	DO NOT DILUTE	
-60	Antifreeze	WITH WATER OR	
-75	preferred	ANY OTHER	
		SUBSTANCE	

1 Maximum protection is obtained at 68 percent by volume, that is 5.4 pints of ethylene glycol per gallon of solution.

2 Military Specification MIL-C-11755 Arctic type, nonvolatile antifreeze compound is intended for use in the cooling system of liquid-cooled internal combustion engine for protection against freezing primarily in Arctic regions where the ambient temperature remains for extended periods of time close to -40°F or drops below, to as low as -90°F.

3 Use an accurate hydrometer. To test hydrometer, use 1 part ethylene glycol type antifreeze to 2 parts water. This should produce a hydrometer reading of 0°F.

NOTE—Fasten a tag near the radiator filler cap indicating the type of antifreeze.

- Check the electrolyte level in the batteries; add distilled water as necessary. Ensure the level is about 3/8 inch above the battery plates. Never add water from a metal container to batteries. Refer to TM 9-6140-200-14 or Chapter 5 of this manual for additional battery services.

WARNING

Do not smoke or use an open flame near a battery. Batteries generate hydrogen gas, which is highly explosive. Handle electrolyte with extreme care. Electrolyte contains sulfuric acid, which severely burns skin, clothing, and paint on contact. Immediately flush water over any area that comes in contact with electrolyte to wash away all traces of acid.

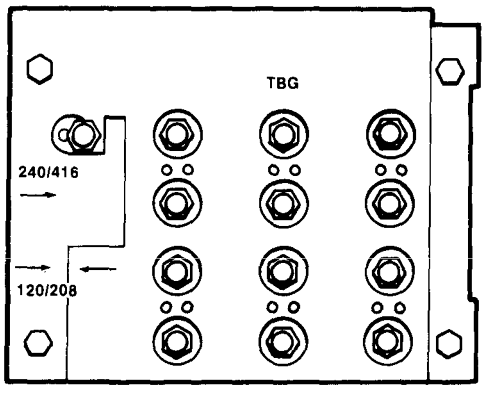
- Tools are used to install and maintain a generator set. Operators must ensure all required tools, technical manuals, and basic issue items on the inventory list are on hand and are serviceable. Included in the basic issue items are an auxiliary fuel hose, grounding rods and cables, a fire extinguisher, paralleling cable, load terminal wrench, and grounding wire clamps. Most generator sets have a storage compartment for the tools, technical manuals, and basic issue items.

- Check the engine oil level; add oil if necessary. Lubricate all other parts according to the lubrication order issued with the equipment.

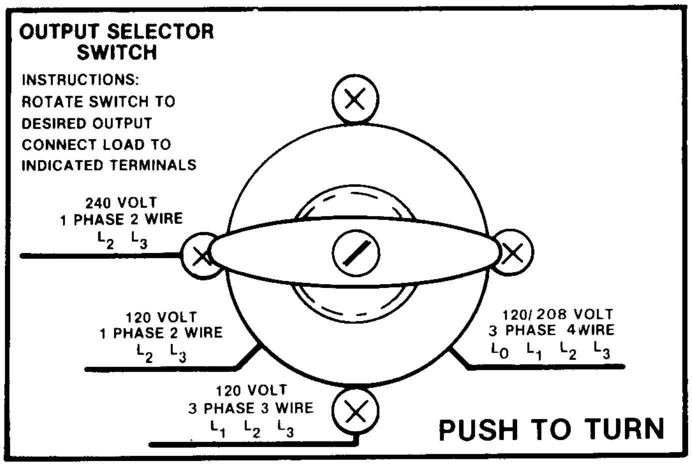
- Carefully check the fuel tank, radiator, oil covers, and oil pan for leaks. Check all lines and connections for leaks.

- Ensure all generator and engine instruments are securely mounted, properly connected, and undamaged. Check all gages when the generator is operating to ensure they work properly.

- Inspect the entire generator set for cracks, breaks, and loose or missing hardware. Inspect all wires and terminals for damage and loose connections. On gas turbine units, inspect the air inlet screen assembly and remove obstructions. Inspect the changeover board and phase selector switch (figure on page 47) for the correct link connections or positioning for the desired voltage. Set the frequency selector switch for the desired frequency output on the 50/60 cycle, precise class 1 sets. Place the circuit breaker (main switch) in the open (off) position. Connect the output service cable to the load panel terminal connections.



TYPICAL CHANGEOVER BOARD



PHASE SELECTOR SWITCH

CAUTION

Never attempt to start a generator set with the circuit breaker closed (on). A closed circuit breaker will cause a power surge and damage the equipment.

- Ensure the grounding connections (figure on page 48) on the equipment and the grounding rod are tight. Use No 6 American wire gage or a larger wire for the ground.

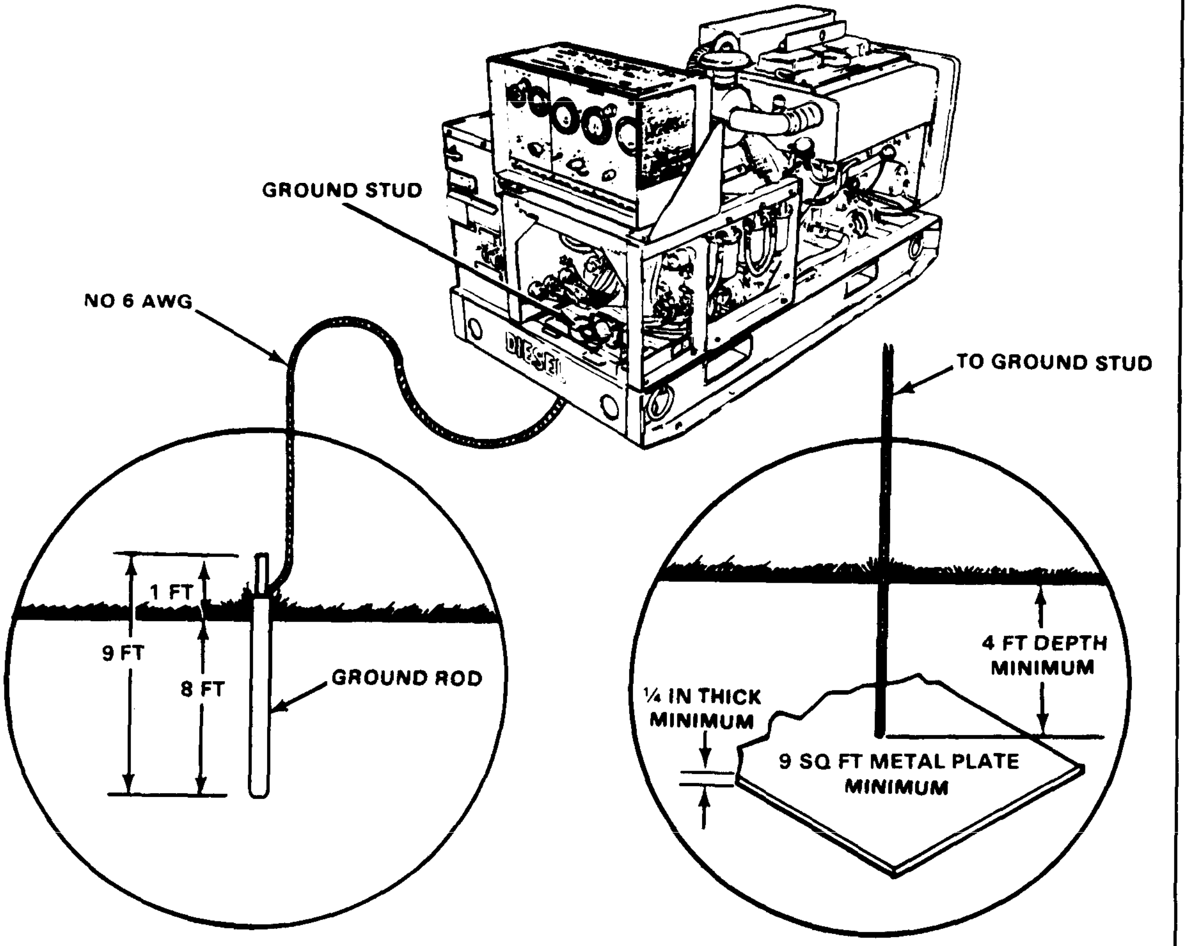
CONNECTION INSTRUCTIONS

After the preliminary tasks are completed, the operator must install and connect the distribution cables.

Install the Distribution Cable

A distribution cable connects the generator set to the load. The cable may be installed overhead, buried underground, or laid on the ground. TWO types of distribution cables are used in military–constructed distribution systems:

- Cable supplied in predetermined lengths and sizes and equipped with quick–disconnect connector plugs.



GROUNDING CONNECTION

- Building wire, supplied in rolls.

The operator must decide how the distribution cable is installed. The method used depends on the type of material available and the conditions at the field unit.

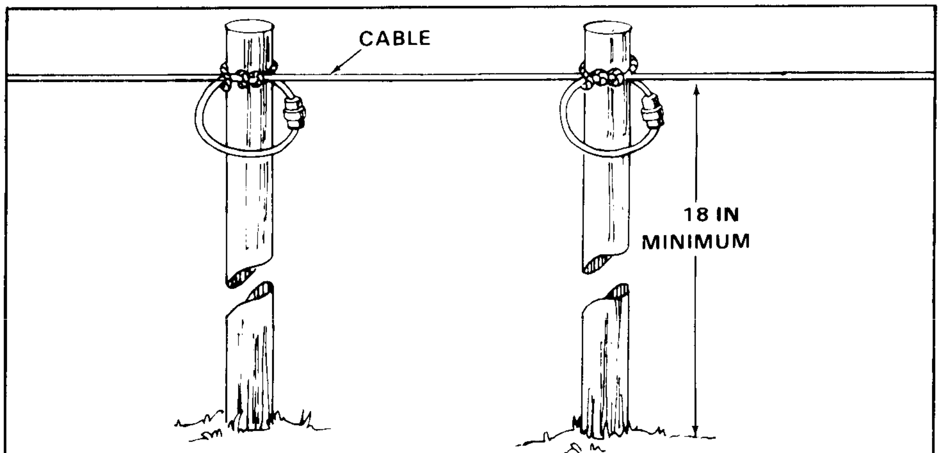
Overhead. When conditions dictate the use of an overhead line, it must be constructed properly. utility poles, the most convenient method of supporting the lines, seldom are available in the field. Pieces of wood 6 inches by 6 inches in width may be substituted for poles if they are long enough to set rigidly in the ground and provide safe clearance for the wires. Trees may be used for support as a last resort if the proper weatherproof cable is available. Use the following guides when installing an overhead distribution system:

- Allow a minimum height of 20 feet for vehicle clearance when crossing over roads.

- Space the poles so the joints where the cables connect are supported by the pole, as shown in the figure below.

- Tie the cable with the quick-disconnects together.

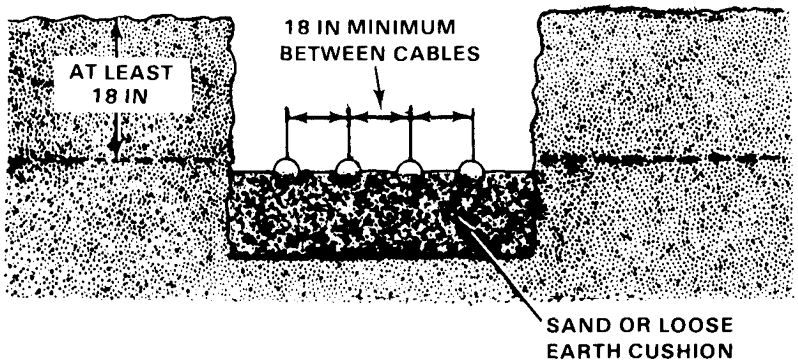
- Use the proper plug connections when installing multiphase cables equipped with quick-disconnects. This type of cable has male and female receptacles that must be properly aligned to prevent a reverse power condition in the system. Match the cable markings or apply markings before installing the cable to ensure proper alignment. Most cables are marked by the manufacturer. The marks are countersunk circular or triangular depressions or raised buttons in the insulation on each receptacle. Most receptacles have one pin and one jack larger than the other pins and jacks. The large pin and large jack represent a grounding (neutral) conductor. Match the large pin and large jack to ensure the receptacles are connected properly if there are no other markings. If the cable is marked at the field unit, paint a color code on the receptacle.



OVERHEAD DISTRIBUTION SYSTEM WITH QUICK-DISCONNECTS

Underground. Sometimes the cable must be buried underground. Use the following guides to ensure proper cable installation underground:

- Dig a trench that is at least 18 inches deep. This depth will prevent the cable from being disturbed by surface digging (figure on page 50).



BURIED CABLE SHOWING PROPER SPACING AND DEPTH

- Use only moistureproof cable. Lay the cable in the trench on a cushion of sand. If sand is not available, loosen the trench base and remove all rocks and stones.

- Ensure the joints are moistureproof if the cable is equipped with quick-disconnects.

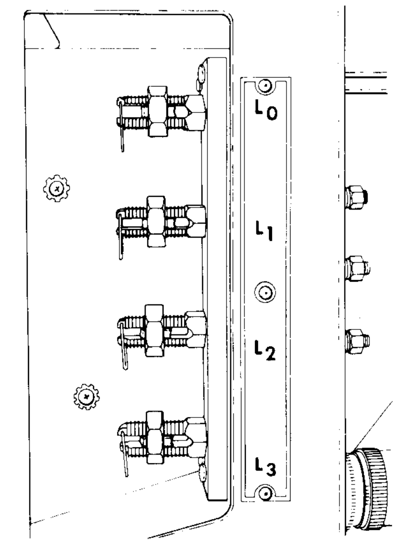
- Separate the cables uniformly to protect the circuits. Allow a minimum of 6 inches between the cable centers for mechanical and electrical protection.

- Cover the cable with earth that has no rocks or stones. This procedure should protect the cable if the surrounding earth is disturbed by flooding or frost heaving.

On the ground. Most cables are laid on the ground to save time. Because many mobile generator sets can be moved almost to the point of use, it may be necessary only to lay the cable over the ground to the load. Protect the cable from mechanical damage by laying planks or logs on both sides of it. This prevents vehicles from driving directly on the cable. Lay the cable where it will have the least interference from personnel operations, and install warning signs indicating the cable location. Use only moistureproof cable that can withstand inclement weather.

Connect the Distribution Cable

Electric power is distributed to the load in a direct line from the generator set or it is processed through a load terminal board. A direct line is used when relatively few items make up the load and when the phase requirement is fairly constant. A load terminal board is used when many items make up the load, the loads are scattered, and the phase and voltage requirements differ. In either case the load must be balanced between the phases, as explained in the previous chapter.



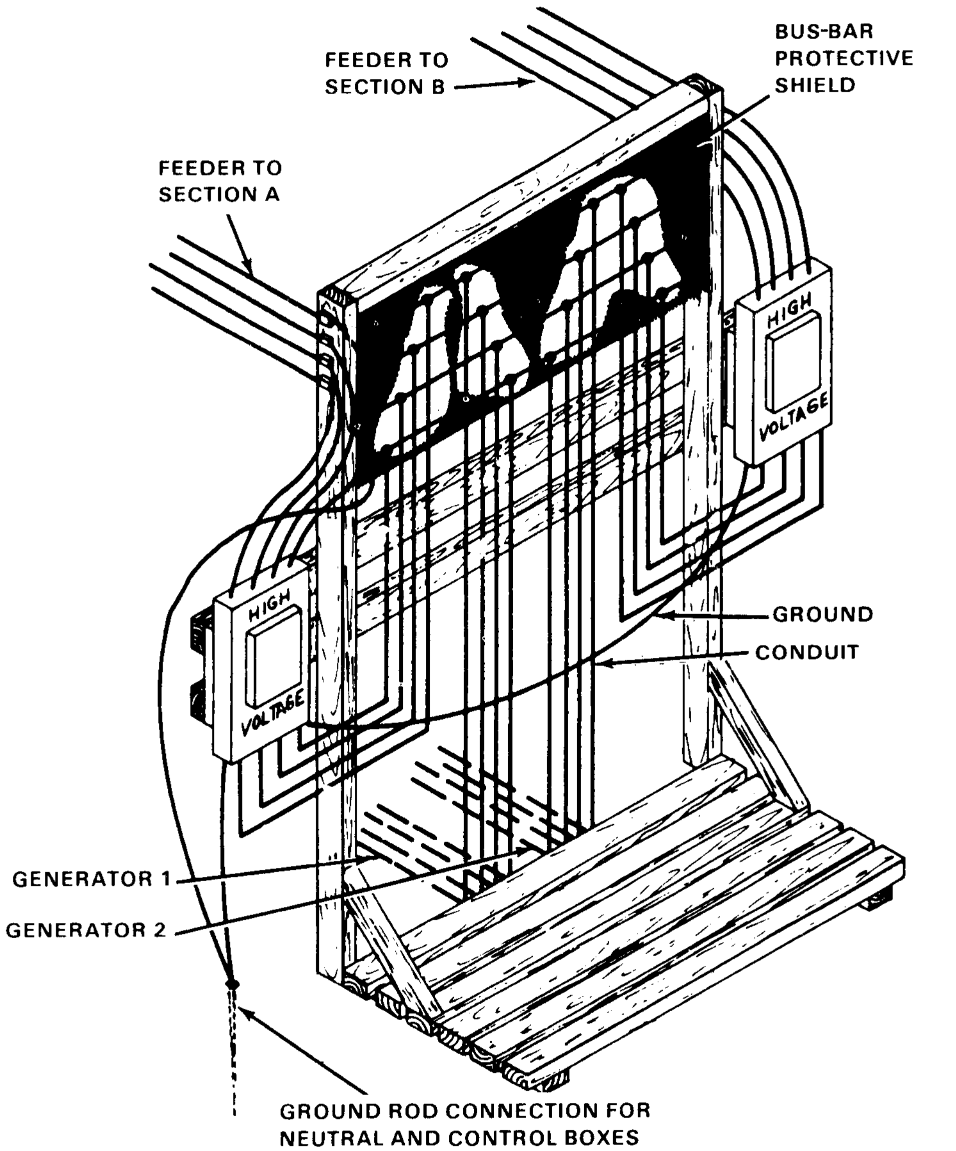
LOAD TERMINAL BOARD

All AC generator sets are equipped with a load terminal board. The board has four terminals marked Lo, L_1, L2, and L3. The terminals simplify the process of connecting the distribution cable at the generator.

A field unit may use a distribution center when no generator set large enough to supply the total electrical load is available. In this situation it is necessary to make parallel connections between two or more sets and distribute their total load through a bus-bar distribution center (figure on page 52). A bus-bar distribution center is also used when the equipment requiring power is so widely scattered that two or more branch-feeder lines are required. Power to the branch-feeder lines is controlled from the bus-bar distribution center.

Perform the following checks before connecting a distribution system:

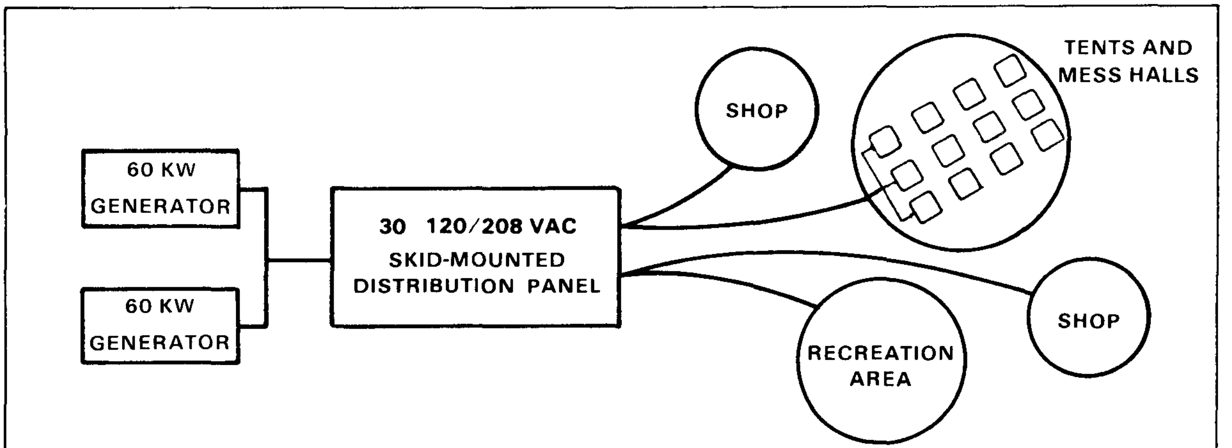
- Ensure all equipment is securely mounted, securely supported, and properly insulated.
- Select the proper size of wire to connect the load. The size of wire used depends on the load current. Refer to the table on page 18 to select the proper wire size.
- Ensure the current rating of the fuses or trip elements provide adequate protection against overloads and short circuits on the branch-feeder lines. The switches that control the output to each branch–feeder line are of two types: The circuit breaker and the fused–knife switch. The operator must be sure that the components of the circuit breaker (contact points) or fused-knife switch (switch blades) can carry the rated current and voltage of the branch-feeder lines.



TYPICAL BUS-BAR DISTRIBUTION CENTER

- Protect the switch gear and bus bar from inclement weather. Equipment damaged by rain or snow can injure personnel when they contact the electrical distribution devices. A weatherproof canopy provides adequate protection.

The layout of a typical distribution system is shown in the figure below. Shielded cables of various lengths connect the loads in four central areas to the power equipment. The shielding on each cable must be grounded at one end as a safety precaution.



LAYOUT FOR A DISTRIBUTION SYSTEM

Power distribution in the central areas usually requires three-conductor, stranded-copper cable. Use the tables on pages 19 and 20 to compute the proper wire size. Operators must use three-phase voltage that ranges from 120 volts to 208 volts.

ADVERSE OPERATING CONDITIONS

Generator sets are designed to operate under adverse conditions. The procedures required to operate equipment under different adverse conditions follow:

Extreme Cold

Generator sets can start and operate at temperatures of -25°F (-32.7°C) without a winterization kit. When the ambient temperature is -25°F (-32.7°C) or lower, most engines require preheating before they are started. The engine type determines the method used. For example, a blowtorch is used on most air-cooled engines. Most liquid-cooled engines are equipped with a winterization kit that contains a preheater. Refer to the manual issued with the generator set for preheating and cold weather starting instructions. Some general checks for starting equipment in cold weather follow:

Cooling systems.

- Before installing a generator set in extreme cold, check the equipment manual for installation instructions. The two basic types of cooling systems used on power generating equipment are air-cooled and liquid-cooled.
- Check the antifreeze solution. Ensure it will protect the equipment at the lowest temperature expected. Use the information in the table on page 45 to mix antifreeze.
- Inspect the level of the coolant in the radiator. Keep the radiator filled to the proper level.
- Inspect the cooling system frequently for leaks. Check all gaskets and hose connections.
- Check the thermometer (water temperature gage) during operation for abnormally high readings.
- Ensure all shutters, shutter controls, and thermostats function properly.
- Ensure the shutters and the baffle rods on air-cooled systems are positioned for cold weather operation.
- Report all uncorrectable faults to organizational maintenance.

Electrical system.

- Ensure the batteries are fully charged to prevent freezing.
- Inspect the electrolyte level daily. The electrolyte level must be 3/8 inch above the battery plates.
- Keep the batteries clean and free of ice, moisture, and corrosion.
- Ensure the battery connections are clean, lightly greased, and tightly secured.
- Ensure the battery cap vent holes are open.

CAUTION

Water added to a battery may freeze unless it is immediately mixed with electrolyte by charging. Do not add water unless the engine is immediately operated for 1 hour or longer.

- Inspect all electrical wiring insulation for cracks, frays, and breaks.
- Tighten loose connections. Report all defective wiring to organizational maintenance.

CAUTION

Disturb the wiring as little as possible. Wire insulation becomes brittle and breaks easily in extreme cold.

Fuel system.

- Keep the fuel tank as full as possible to reduce condensation.
- Ensure the proper grade of fuel is used for existing temperatures.
- Service the fuel filters more frequently than usual to remove water from the fuel system.
- Keep the fuel tank cap and filler necks free of ice, snow, and moisture during operation and when refueling.
- Drain the fuel tank if the fuel becomes contaminated and refill it with clean fuel. Drain sediment from the fuel tank daily.

Lubrication. Lubricate the generator set for cold weather conditions according to the current lubrication order.

Cleaning. Remove ice, snow, moisture, or other foreign material from the generator set before each period of operation.

Generator warm-up period. When operating in extreme cold, warm the generator set to the operating temperature before applying the load. Some generator sets are damaged when the engines operate at low revolutions per minute (RPM).

Extreme Heat

Operating electric generators when ambient temperatures are high requires efficient equipment cooling and adequate lubrication. General checks and services required to operate equipment in extreme heat follow:

- Provide maximum ventilation for the cooling systems at all times. Keep the equipment clean, especially the engine shrouds and cooling fins, and the generator blower cover. Ensure all air passages are free of obstructions. Move all shutters and baffle rods to the proper position.

- Inspect the coolant level frequently, and add clean coolant as needed. To keep the cooling system free of rust and scale, add an approved rust inhibitor and flush the cooling system regularly. Do not use alkaline or salt water as a coolant. Ensure the radiator core fins and screens are free of obstructions. Ensure the fan-drive V-belt tension is adjusted properly. Ensure the radiator shutter operates properly. If the automatic shutter control (thermostat) fails, open and close the shutter manually. Report the failure to organizational maintenance. Refer to the appropriate technical manual to determine if the panel doors should be opened or closed.

- Inspect the electrolyte level of the batteries daily, and add distilled water as needed. The electrolyte level must be 3/8 inch above the battery plates. Keep the batteries clean and free of corrosion. Inspect the terminals for corrosion and loose connections frequently. Corroded and loose connections generate heat during operation, and extreme heat causes the wiring insulation to swell and soften. Chafing and fraying of the wires due to vibration are more frequent during extreme heat than in other conditions. Inspect the wiring for damaged insulation frequently. Report damaged insulation to organizational maintenance.

- Lubricate the generator set according to the current lubrication order.

- Provide ample air circulation around the generator set if it operates in an enclosed shelter. Allow air from outside to circulate within the shelter. Keep the main generator's ventilation screen and louvers free of obstructions. Inspect the instruments on the control panel frequently for overloads. Overloads cause the main generator to overheat and may cause the main circuit breaker to open. Do not fill the fuel tank completely; allow room for fuel expansion. Before an operating set is shut down, run it without the load to cool the engine.

Dusty and Sandy Areas

Perform the following checks when operating electric power generating equipment in dusty and sandy areas:

- Erect a protective shield for the generator set to provide wind protection. Dust and sand cause mechanical failures and shorten the life of the equipment. Natural barriers can form a wind shield. For example, locate the generator set on the prevailing windward side of dusty areas, roadways, and construction sites.

- Clean the generator set frequently with an approved cleaning solvent. Keep the unit clean, especially the screens and grilles. When water is plentiful, wet the terrain surrounding the immediate operating area.

- Keep all equipment clean. Keep the main generator free of grease and oil. Clean obstructions from the ventilation screens. Blow dust and sand from electrical components with low-pressure, dry, compressed air.

- Inspect the cooling system frequently for leaks. Ensure the radiator and shutter operate properly and are free from obstructions. Keep the radiator cap tightly closed. Drain and flush the cooling system more frequently than required for normal conditions. When adding coolant, take any precautions needed to keep dust and sand from entering the cooling system.

- Maintain lubrication. Lubricate the generator set according to the current lubrication order. Keep all lubricant containers tightly sealed, and store them in an area free from dust and sand. Service the engine oil, oil filter, and air cleaner more frequently than required for normal conditions. Clean all lubrication points before applying lubricants. Clean around the crankcase oil fill cap and crankcase oil level gage before checking the oil level or adding oil.

- Prevent dust and sand from entering the fuel system. Inspect the fuel filter after each operating period. Clean the filters and strainers more frequently than required for normal conditions.

- Check the air cleaner for restrictions frequently.

Rainy and Humid Areas

Perform the following checks for power generating equipment used in rainy and humid areas:

WARNING

Keep the area surrounding a generator set dry at all times. Use insulating materials around the set if conditions are damp to avoid serious shocks.

- Provide protection from rain. Keep all doors and panels on the generator closed when the set is not in use. Open the doors and panels during dry weather so the equipment can dry.

- Keep electrical equipment dry to prevent corrosion, deterioration, and short circuits. Inspect all electrical wiring for cracks, breaks, or frays. Report defective wiring to organizational maintenance.

- Keep the fuel tanks as full as possible so moisture cannot accumulate in them. When adding fuel, ensure no water enters the fuel system. Keep the reserve fuel containers tightly closed. Drain contaminated fuel tanks, and refill them with clean fuel.

Saltwater Areas

Salt water is corrosive to metal. It is an excellent conductor of electricity. Perform the following checks and services on equipment operating in saltwater areas:

- Ensure the electrical equipment is never in contact with salt water. If contact occurs, wash the equipment with fresh water and allow it to dry thoroughly before operating it.

- Cover nonoperating generator sets that are outside with canvas or other weatherproof material.

CAUTION

Do not use salt water in the cooling system of a generator set except in an emergency. Salt water damages the equipment.

- Ensure the coolant used in the cooling system is free of salt. Use an approved rust inhibitor to prevent rust and scale from forming in the cooling system.

- Paint all exposed, nonpolished surfaces. Coat exposed parts of polished steel and other ferrous metals with standard issue rust-proofing material or a light coat of grease.

High Altitudes

Generator sets are rated based on sea level altitude. The rating of the set may decrease as the altitude increases. Information about operating equipment at high altitudes usually is printed on the data plate. The kilowatt rating may be reduced at high altitudes depending on the type of engine used to drive the generator. Refer to the appropriate technical manual for information about each model of generator set.

Combat Areas

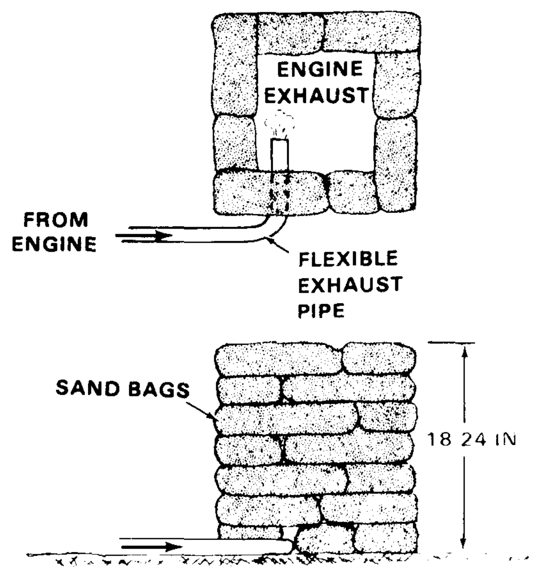
Operating generator sets in combat areas requires special precautions. It is difficult to operate electric generators without making the location known to the enemy. The equipment is noisy and produces large amounts of heat, which may endanger personnel and equipment nearby. The discomfort caused by the noise and heat may result in decreased performance of mission goals by personnel. The ability to hear enemy activity may be reduced. New signature-suppressed generator sets that reduce noise levels are being studied. These sets will be available to field units in the future.

WARNING

> Do not overload a generator set. Heavily loaded generators produce excessive noise, dangerous sparks, and hot exhaust gases that can injure personnel.

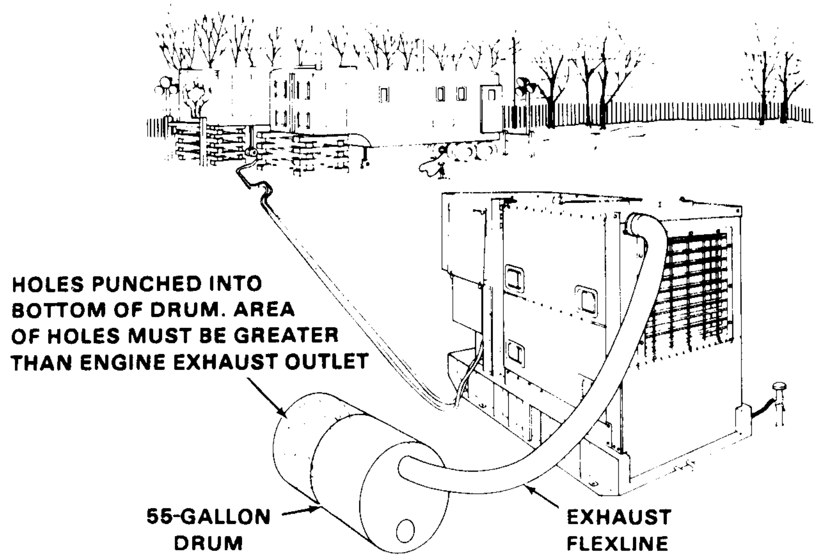
Major sources of noise associated with generator sets are the engine exhaust system, air intake cooling fan, and vibrating metal. Operators in combat areas can use several methods to reduce the noise from operating generators. The methods used depend on the size of the generator set.

Sets producing 0.5 kw through 10 kw of electricity. The most effective method of suppressing the noise from small-sized generator sets is to install them in a revetment (figure on page 38). Connect an auxiliary exhaust line from the engine to the revetment chimney to remove the exhaust, as shown below. An empty 55-gallon oil or fuel drum can be



SANDBAG EXHAUST CHIMNEY

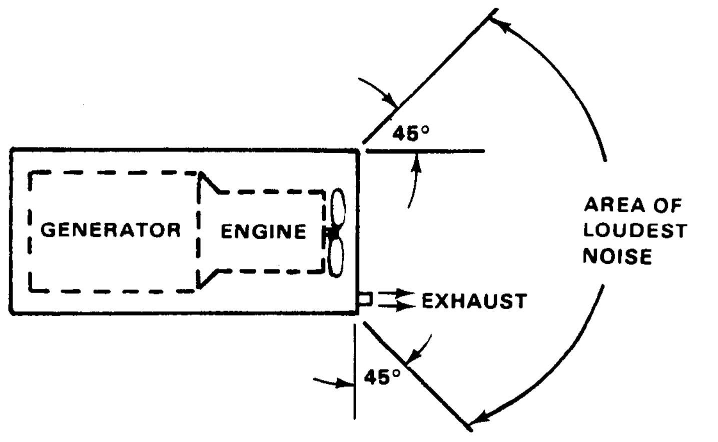
substituted for a sandbag chimney. To do this, punch a number of small holes in the bottom of the drum. The area with holes must be the same size or larger than the area of the engine exhaust. Lay the drum on its side and insert the auxiliary exhaust line inside the large hole in the drum, as shown below. Use any flexible or rigid metal pipe that has a diameter larger than the exhaust outlet on the engine muffler.



EXHAUST NOISE SUPPRESSION

To reduce mechanical noises and the noise from the engine fan, locate the generator behind a barrier such as a hill, dense woods, large vehicle, or plywood wall. Do not restrict air flow around the engine. An air-cooled engine operating in a confined area such as a foxhole will severely overheat and possibly destroy itself in hot weather.

Sets productng 15 kw through 500 kw of electricity. The noise from medium– and large-sized diesel generator sets with liquid-cooled engines is very loud at the radiator end of the set. The main sources of noise are the radiator cooling fan and exhaust, as shown on page 61. Operators in long-term field units can build underground muffler systems for medium- and large-sized sets. Even with an underground exhaust system, the noise level will be high because of the unsuppressed fan noise. To reduce the fan noise, place a barrier such as a van, plywood sheets, or convex containers in the noise, path. Another option is to locate the equipment so that a natural barrier lies between the radiator and the direction where the noise reduction is desired. Do not restrict air flow out of the radiator.



AREA OF LOUDEST NOISE

Another problem in combat areas is that the equipment may be seen by the enemy. It may be necessary to camouflage the equipment and revetments to avoid detection.

Generators have a thermal signature that can be detected by infrared sensors. At this time there is no way to eliminate this problem.

Ice fog caused by engine exhaust is a problem in very cold climates (-25°F and below). To eliminate ice fog, install a tube to the exhaust pipes. Cover the tube with a tarpaulin to diffuse the exhaust in the snow.

Operators in combat areas must use any means available to avoid detection by the enemy.

Chapter 4

Controls and Instruments

A complex set of controls and instruments monitors the operation of an electric generator set. Equipment operators must understand what these controls and instruments monitor and how they work. Information about many controls and instruments is included in this chapter. Additional information about the controls and instruments for a specific generator set is in the manual issued with the set.

ENGINE CONTROLS

The controls and instruments used to operate a generator set are installed in a control panel similar to the one on page 63. Descriptions of many of these controls follow. The number in parentheses after the control name corresponds to the callout in the illustration.

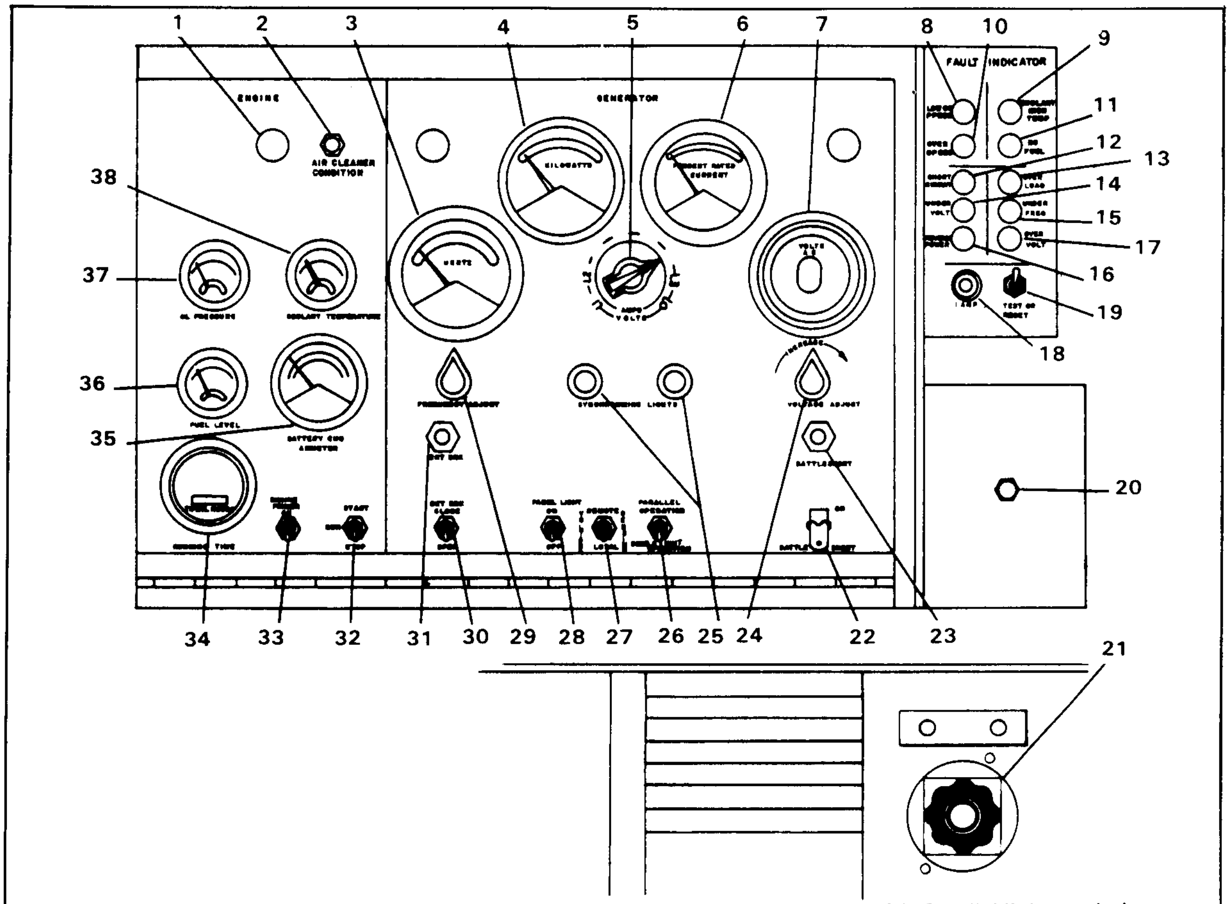
DC circuit breaker (20). Protects DC circuits against shorts and emergency stops.

Start-run-stop switch (32). When pressed in the start position, this switch completes the battery circuit to start the motor. The switch is released and returns to the run position after the generator starts. The switch remains in the run position until placed in the stop position.

Manual speed control (21). Regulates the speed of the engine.

Engine heater controls (figure at the upper left of page 64). Operate the engine's heater. The control set includes a circuit breaker, a heater on indicator light (press-to-test light), and an on-off switch. The press-to–test light is on when the heater is operating.

Three-way fuel valve (figure at upper right of page 64). Directs the flow of fuel from the source of supply to the fuel pump. The valve has three positions––auxiliary fuel tank, set fuel tank, and off. The first two positions indicate the fuel source. For example, when the valve handle is in the set fuel tank position, fuel is drawn from the tank on the generator set.

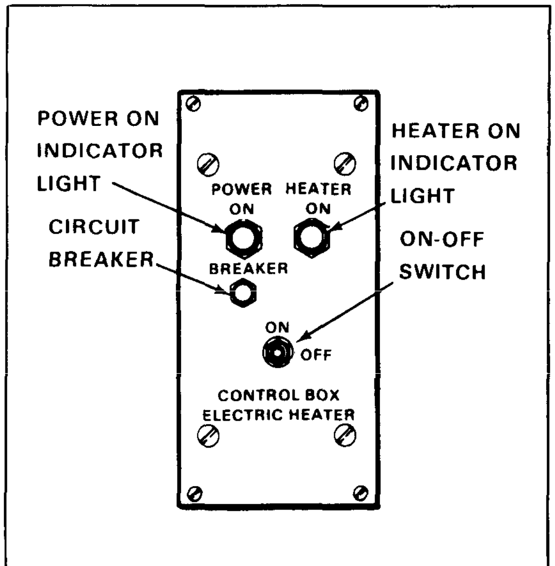


1. Panel illumination light
2. Air cleaner condition indicator
3. Frequency meter
4. Kilowatt meter
5. Volts-amps selector switch
6. AC ammeter
7. AC voltmeter
8. Low oil pressure indicator
9. Coolant high temperature indicator
10. Overspeed indicator
11. No fuel indicator
12. Short circuit indicator
13. Overload indicator
14. Under voltage indicator
15. Under frequency indicator
16. Reverse power indicator
17. Over voltage indicator
18. Fault location indicator fuse
19. Test or reset switch
20. DC circuit breaker
21. Manual speed control
22. Battle short switch
23. Battle short indicator
24. Voltage adjust rheostat
25. Synchronizing lights
26. Parallel lights switch
27. Voltage sensing switch
28. Panel light switch
29. Frequency adjust rheostat
30. Circuit breaker switch
31. Circuit breaker indicator
32. Start-run-stop switch
33. Engine primer switch
34. Hour meter
35. Battery charge ammeter
36. Fuel level gage
37. Oil pressure gage
38. Coolant temperature gage

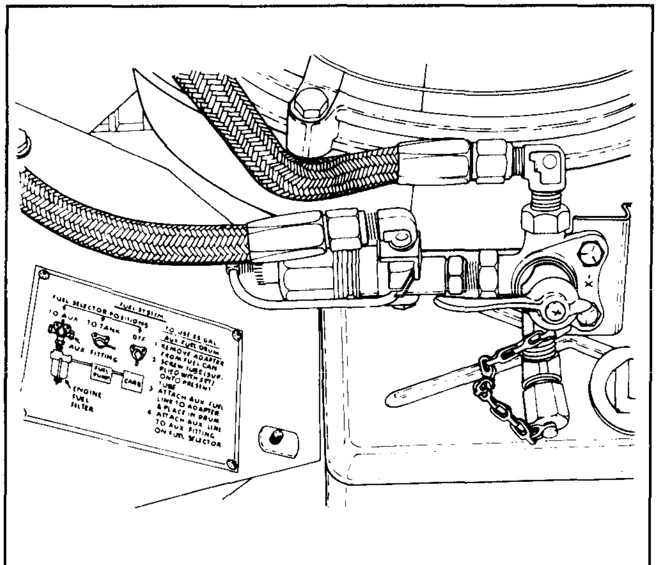
TYPICAL CONTROL PANEL

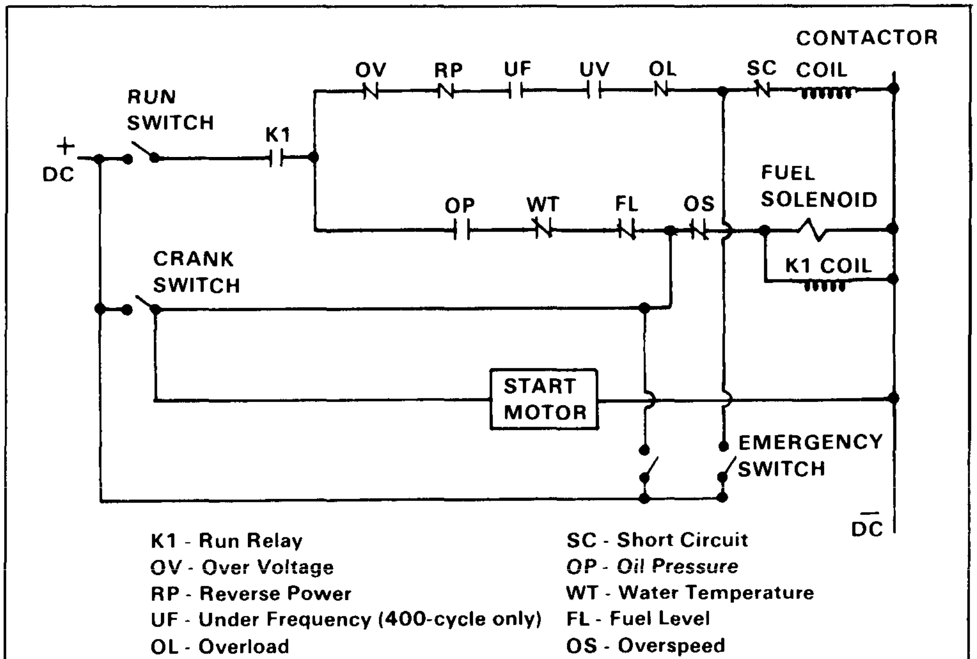
SAFETY CONTROLS

Most generator sets have a safety control system similar to the one in the figure at the bottom of page 64. The system consists of relays, overspeed safety devices, and pressure-temperature controls. The generator shuts down when a safety device actuates. Safety devices stop the engine or



TYPICAL ENGINE HEATER CONTROLS


THREE-WAY FUEL VALVE



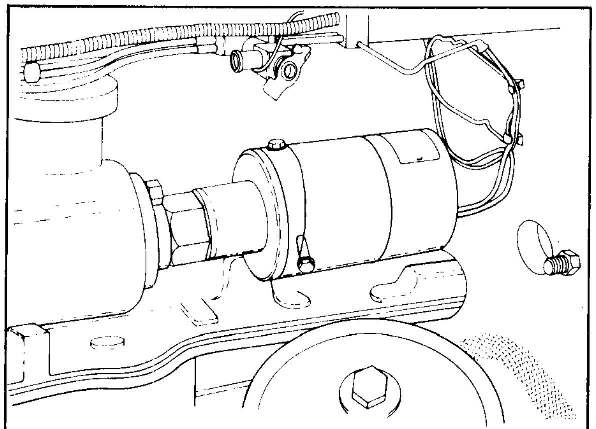
PRACTICAL WIRING DIAGRAM OF A SAFETY CONTROL SYSTEM FOR A TYPICAL MOBILE GENERATOR SET

trip the circuit breaker in cases of overspeeding, low fuel level, low oil pressure, or high coolant temperature.

Low oil pressure indicator (8). Illuminates when the oil pressure drops enough to actuate the low oil pressure safety device.

Coolant high temperature indicator (9). Illuminates when the coolant temperature rises enough to actuate the coolant high temperature safety device.

Overspeed indicator (10). Illuminates when the engine speed exceeds the rated RPM and the overspeed safety device actuates.



OVERSPEED SAFETY DEVICE

No fuel indicator (11). Illuminates when fuel in the tank is low enough to actuate the no fuel protective device.

Battle short switch (22). Permits emergency operation of the generator. This four-pole, on-off switch prevents the generator from starting after a safety device actuates by locking out the starter circuit. It bypasses all protective device circuits except the overspeed and short circuits. During normal operations the battle short switch is in the off position.

ENGINE INSTRUMENTS

Several instruments monitor the engine's operation. Most of the following instruments are on the control panel shown on page 63:

Oil pressure gage (37). Indicates the amount of oil pressure maintained in the engine.

Coolant temperature gage (38). Indicates the temperature of the engine coolant.

Fuel level gage (36). Indicates the amount of fuel in the main tank.

Battery charge ammeter (35). Indicates the condition of the batteries and charging system.

Hour (Time-totalizing) meter (34). Indicates the amount of time the generator set has operated.

Exhaust gas temperature gage (not shown). Indicates the temperature of exhaust gases during engine operation. This gage is only on gas turbine engine-driven generators.

Tachometer (not shown). Indicates the engine speed at any time during operation. This meter is only on gas turbine engine-driven generators.

AC GENERATOR CONTROLS

The following controls monitor the operation of an AC generator. The number in parentheses corresponds to the callout on the control panel on page 63.

Volts-amps selector switch (5). Provides current and voltage readings for each generator phase. A meter is connected to each phase of the main generator. Most switches have six positions that are plainly marked on the face of the selector plate.

Phase selector switch (figure on page 47). Changes the output of a generator to match the voltage and phase requirements of the load. This rotary-type switch is used on generators that produce as much as 10 kw of electricity; changeover boards are used for generators that produce 15 kw or more.

Parallel lights switch (26). Closes the synchronizing lights circuit in preparation for paralleling two or more power units. It usually is a two-position, rotary or toggle switch.

Voltage adjust rheostat (24). Adjusts the value of the output voltage. The rheostat is a small, variable resistor.

Circuit breaker switch (30). Disconnects and connects the load lines from the generator set. Acts as a main switch and as an overload protective device. The circuit breaker automatically disconnects the load from the generator in case of overload, short circuit, or ground on the load lines or within the equipment being powered.

AC GENERATOR METERS

The following meters monitor the output from an AC generator:

AC ammeter (6). Indicates the current output of the generator. The output usually is a percentage of the rated load.

AC voltmeter (7). Indicates the voltage of the output terminals and, therefore, the voltage output of the generator.

Frequency (Hertz) meter (3). Indicates the line frequency of the generator output in cycles per second. This dial-type meter is used for 50-, 60-, and 400-cycle generators.

Kilowatt meter (4). Indicates output from the generator. The output reading, in percent of kilowatts, must not exceed the rated capacity of the power plant. The operator must reduce the load if the output reading exceeds the rated capacity of the power plant.

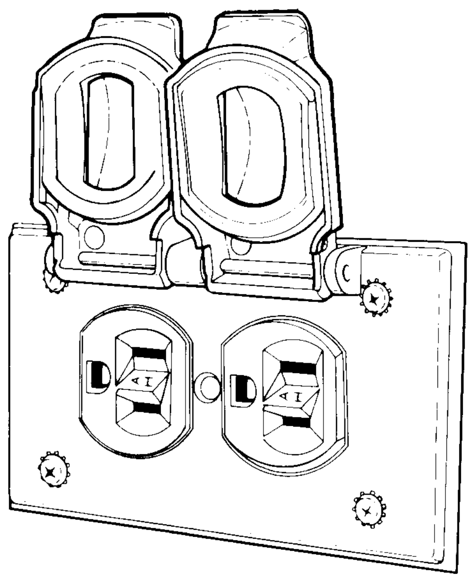
MISCELLANEOUS CONTROLS AND ACCESSORIES

The following controls operate the winterization equipment. The convenience outlets are used with AC generators.

Heater onloff switch (figure on upper left of page 64). Turns the engine heater on and off.

Heater circuit breaker. Protects the heater's electrical circuit from accidental overloads.

120-volt AC convenience outlets. Provide outlets for lights around the generator set. Fuses or a circuit breaker protect the outlets from overloads.



CONVENIENCE OUTLET

Chapter 5

Maintenance and Repair Procedures

Regular and systematic maintenance helps ensure that a generator operates as required at all times. Preventive maintenance Is important because it allows the operator to discover and correct defects before they cause serious damage or equipment failure.

This chapter describes the maintenance procedures required for all electric generator sets. Refer to the operator's manual for the PMCS required for a specific generator.

PREVENTIVE MAINTENANCE

Equipment operators must identify and write down all faults or shortcomings they discover. They must stop operating the equipment immediately if the deficiency could endanger personnel or damage the equipment. Operators can repair most of the faults they identify. If they cannot or if replacement parts are required, the operator must record the problem or defective part numbers on a DA Form 2404 and submit the form to organizational maintenance. The use of DA forms is explained in DA Pam 738-750.

Regular PMCS are performed on the following generator systems:

- Lubrication.
- Cooling.
- Fuel.
- Electrical.

Lubrication System

Crankcase and crankcase breather. Inspect for leaks around the crankcase. Replace defective breathers. Ensure the oil in the crankcase is at the proper level.

Oil filter. Inspect the oil filter for loose or missing mounting hardware. Tighten the hardware and replace worn parts. Inspect the oil lines for leaks, breaks, or wear. Service the filter as directed in the lubrication order.

Cooling System

Radiator, grille, and shutter. Inspect the radiator, grille, and shutter for leaks, loose mounting, or obstructions in air passages. Inspect all lines and connections for leaks. Check the hoses for signs of deterioration and loose connections. If antifreeze is used, record the freezing point on the maintenance records. Drain, flush, and refill the cooling system if the coolant is contaminated. Replace defective hoses, lines, and gaskets. Ensure the manual shutter control operates properly.

Water pump, fan, and fan guard. Inspect the water pump for cracks, leaks, loose or missing mounting hardware, or other damage. Inspect the fan and fan guard for loose mounting.

Fan-drive V-belt and pulleys. Inspect the fan–drive V-belt for wear. Replace frayed or worn belts. Check for proper alignment and tension between the pulleys, as prescribed in the technical manual.

Thermostat housing. Inspect the thermostat housing for cracks.

Fuel System

Fuel pump. Inspect the fuel pump for leaks, damage, and loose or missing mounting hardware.

Fuel filters. Inspect the primary and secondary fuel filters for loose or missing mounting hardware, cracks, leaks, or other damage. Service the filters as required in the technical manual.

Fuel supply. Ensure enough clean fuel of each required type is available for the planned period of operation.

Fuel tank, cap, and gasket. Inspect the fuel tank for leaks. Drain sediment from the fuel tank. Inspect the cap and strainer for dirt, wear, and defects. Inspect the chain and gasket for wear. Open or close the cap vent as required.

Fuel lines and fittings. Inspect the fuel lines and fittings for cracks, leaks, and loose or damaged connections.

Electrical System

Batteries. Inspect the batteries for cracks, leaks, dirt, and corroded or damaged cables and terminals. Check the electrolyte level. Refer to page 81 for additional battery checks and services.

Engine generator and starter. Inspect the commutator and brushes for wear, tension, dirt, corrosion, and oil deposits. Ensure the brushes move freely in their holders. Ensure all electrical connections are tight and free of corrosion.

Lights, wiring, and switches. Inspect the panel lights for loose connections, loose mountings, and corrosion. Inspect all electrical leads in the engine and the main generator for looseness, breaks, and damaged or worn insulation. Inspect all switches for signs of excessive wear, failure, or other damage.

Engine generator regulator. Inspect the engine generator regulator for external damage.

Gages. Inspect the fuel gage, thermometer (water temperature gage), and oil pressure gage for loose or missing mounting hardware, cracked or broken glass, or other damage.

Meters. Inspect the battery charge ammeter and hour meter for loose or missing mounting hardware, cracked or broken glass, loose connections, or other damage.

Fault indicator panel. Inspect the indicator lights for damage. Test the lights for proper operation.

Rheostats. Inspect the regulator control rheostat and the crosscurrent compensation rheostat for loose connections or other damage. Turn the knobs to the left and right to ensure they operate freely.

Speed control governor. Inspect the speed control governor for excessive wear, loose mounting, or other damage.

Main generator. Inspect the main generator for damage. Blow dust and dirt from the generator housing with a low-pressure, dry air compressor.

Control panel meters. Inspect the frequency meter, AC ammeter, AC voltmeter, and kilowatt meter for loose mountings, loose connections, cracked or broken glass, or other damage.

EQUIPMENT TESTING

An electric generator set is tested before it begins full operation, periodically during operation, and after parts are repaired or replaced. Tests are made to ensure all parts work properly and will not malfunction under different load conditions. Tests also are made to ensure a generator set can maintain a load. Maintaining a load when the set is in operation reduces carbon buildup in the Internal combustion engine.

Operators may test a generator set using the equipment it was designed to power or using a load bank. The load bank method is preferred because it lets the operator set up and control the power specifications. The load bank should be used to test generators that frequently operate with little or no load.

The load bank is a self-contained test unit mounted within a cabinet. It generates no power. Instead, the load bank operates on an external power source through the system being tested. Cables are required to connect the load bank to the generator. Some load banks are designed to operate automatically. Others are operated manually to maintain a minimum load on the generator.

The load test is made by adding increments of resistive or reactive electrical loads to the generator. Operators can change increment combinations to simulate any electrical loads within the bank's rating. For example, the load bank can test the output of generator sets rated for single-phase, two-wire, 120/240 volts; three–phase, three–wire, 240 volts; and three-phase, four-wire, 120/208 or 240/416 volts. The tests can be applied at frequencies ranging from 50 to 1,000 cycles per second.

WARNING

Store and use the load bank only in an upright position, never upside down or on end. Before use, ground the frame to avoid possible shocks. If excessive vibrations or unusual noises occur during operation, turn the load bank off. Shut down the power source before touching, connecting, or disconnecting any electrical leads or parts. Disconnect the load bank from the power source before removing panels. Stop the *load* bank at once if the motor or other components heat up excessively. Use carbon dioxide to put out all electrical fires. Never use water to put out electrical fires.

COMMON EQUIPMENT MALFUNCTIONS

While preventive maintenance usually keeps an electric generator set operating as required, malfunctions sometimes occur. Operators can correct most equipment failures or unsatisfactory performance by using the following Troubleshooting Guide. It identifies common malfunction symptoms, probable causes, and possible solutions. Report to the next higher level of maintenance if the suggested solution does not correct the malfunction.

NOTE: Operators must report all malfunctions beyond the scope of the operator or the crew to organizational maintenance.

Troubleshooting Guide

Symptom	Probable Cause	Possible Solution
Engine hard to start or fails to start	Fuel tank empty	Fill tank
	Fuel filters clogged	Replace filters
	Fuel pump screen clogged	Clean screen
	Foreign material in fuel	Drain tank and refill with clean fuel
	Air cleaner clogged	Clean or replace filter element
	Overspeed switch tripped	Reset switch
	Battery circuit fuse blown	Replace fuse
	Batteries discharged	Charge or replace batteries
Engine stops suddenly	Fuel tank empty	Fill tank
	Fuel filters clogged	Replace filters
	Fuel pump screen clogged	Clean screen
	Auxiliary fuel hose clogged	Clean hose
	Safety device tripped	Inspect engine oil and coolant levels; reset overspeed switch, and operate unit at proper speed

Engine stops suddenly (Continued)	Engine oil level low	Add oil to proper level
	Coolant level low	Add coolant to proper level
	Engine overheating	Provide proper ventilation
	Cooling system clogged	Flush system
	Fan drive V-belt inoperative	Tighten to proper tension
	Shutter control inoperative	Operate shutter manually and report condition to organizational maintenance
Engine oil pressure low	Oil pressure low	Adjust oil pressure
	Engine oil level low	Add oil to proper level
	Oil filter clogged	Replace filter
	Engine oil diluted	Change oil
Engine exhaust smokes excessively	Engine temperature low due to insufficient warm-up time	Allow sufficient time for engine to warm up before applying load to unit
	Engine temperature low due to defective shutter	Operate the shutter manually and report the condition to organizational maintenance
	Engine oil level too high	Drain oil to proper level
	Air cleaner clogged	Clean or replace filter element
	Fuel grade incorrect	Drain tank and fill with the correct grade of fuel

Symptom	Probable Cause	Possible Solution
Engine lacks power	Air cleaner clogged	Clean or replace filter element
	Fuel filters clogged	Replace filters
	Water in fuel system	Drain tank and refill with clean fuel
	Fuel pump screen clogged	Clean screen
	Fuel grade incorrect	Drain tank and refill with proper grade of fuel
Engine knocks or makes excessive noise	Engine oil level low	Add oil to proper level

CAUTION

Stop the engine immediately if the engine knocks or is noisy when the engine oil is at the proper level. Continued operation may cause serious damage. Report the condition to organizational maintenance.

Symptom	Probable Cause	Possible Solution
Starter fails to crank engine	Battery circuit fuse blown	Replace fuse
	Battery circuit breaker tripped	Reset circuit breaker
	Loose or corroded battery cable connections	Tighten and clean connections
	Batteries discharged	Charge or replace batteries
Main generator fails to build up rated voltage	Frequency or voltage too low	Adjust frequency and voltage
	Wiring defective	Inspect wiring; report defective wiring to organizational maintenance

Symptom	Probable Cause	Possible Solution
Main generator voltage too high	Voltage adjusted improperly	Adjust voltage properly
	Frequency adjusted improperly	Adjust frequency properly
Main generator overheats	Generator ventilation doors closed	Open doors
	Generator ventilation screens obstructed	Remove obstructions
	Generator overloaded	Reduce load
Main circuit breaker continues to trip	Generator output voltage too low	Increase output voltage
	Generator wiring defective	Inspect wiring; report defective wiring to organizational maintenance
	Generator overloaded	Reduce load or report condition to organizational maintenance
Frequency drops after increasing generator load	Speed droop adjusted improperly	Adjust droop
Frequency fluctuates	Air cleaner clogged	Clean or replace filter element
	Fuel filters clogged	Replace filters
	Air in fuel system	Prime fuel system
	Governor adjusted improperly	Report to organizational maintenance
Main generator noisy	Object in main generator ventilation screen	Remove object

Symptom	Probable Cause	Possible Solution

CAUTION

Stop operating the equipment immediately if unusual noises are heard. Unusual noises from the main generator usually indicate a part failure. Continued operation may cause additional damage. Report unusual noises to organizational maintenance.

Symptom	Probable Cause	Possible Solution
Instruments fail to function properly	Generator controls adjusted improperly	Refer to operator's manual
	Needle stuck on dial gage	Tap gage lightly with finger
Winterization heater fails to ignite or keep burning	Battery circuit fuse blown	Replace fuse
	Heater fuel filters clogged	Replace dirty filters
	Heater fuel pump screen clogged	Clean screen
	Main fuel tank empty	Fill tank
120-volt AC receptacle will not supply current	120-volt AC receptacle fuse blown or circuit breaker off	Replace fuse or reset circuit breaker
24–volt DC receptacle will not supply current	24–volt DC receptacle fuse blown	Replace fuse

ELECTRICAL DISTRIBUTION CABLE REPAIRS

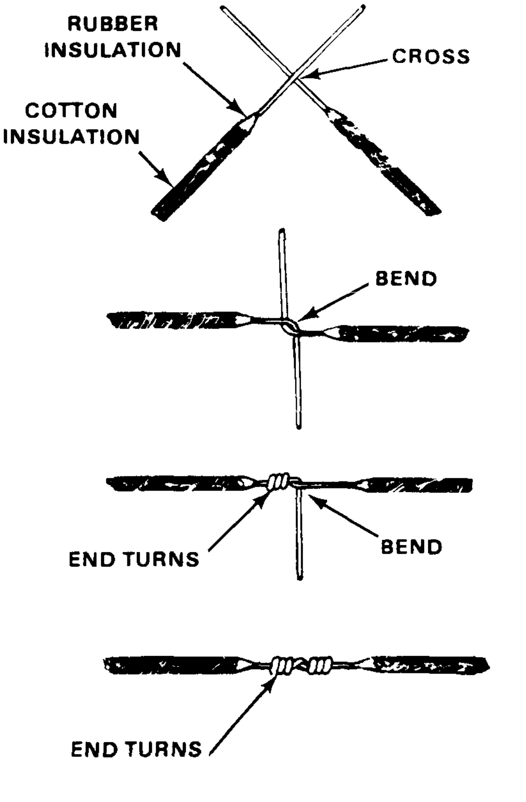
The repair of electrical distribution cables requires special skills and equipment not usually available at the organizational maintenance level. Therefore, equipment operators and crew members are seldom authorized to work on these cables except when tactical conditions require prompt, temporary splicing. The following information describes the types of splices used to repair damaged distribution cables and correct splicing procedures:

WARNING

Disconnect the cable from the power source before inspecting or repairing it.

Splices

Western union. Used to repair solid conductors.



WESTERN UNION SPLICE

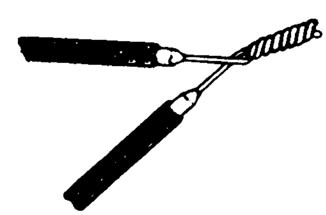
Procedure:

1. Remove sufficient insulation and clean the conductors.
2. Cross the wires and clamp them in the middle with a pair of long-nosed pliers.
3. Grasp the short end of the wire on one side of the pliers, and bend it out and away at a 90-degree angle to the long wire.
4. Wrap the short wire around the long wire using small, tight loops. Make at least three or four loops to ensure a strong connection.
5. Repeat step 4 for the short wire on the other side of the pliers. Wrap the loops in the opposite direction from those on the first wire to add strength to the splice.
6. Crimp down or cut off excess wire on the ends.

Pigtail. Used to add branch circuits on wiring installed in buildings and conduits (steel pipe).

Procedure:

1. Remove sufficient insulation and clean the conductors.
2. Cross the two wires at a 90-degree angle. Allow about 2 inches of overlap.
3. Clamp the wires at the crossing point with a pair of long-nosed pliers.
4. Grasp both short ends between the thumb and first two fingers. Twist the ends to make tight loops. Twist both ends in the same direction.

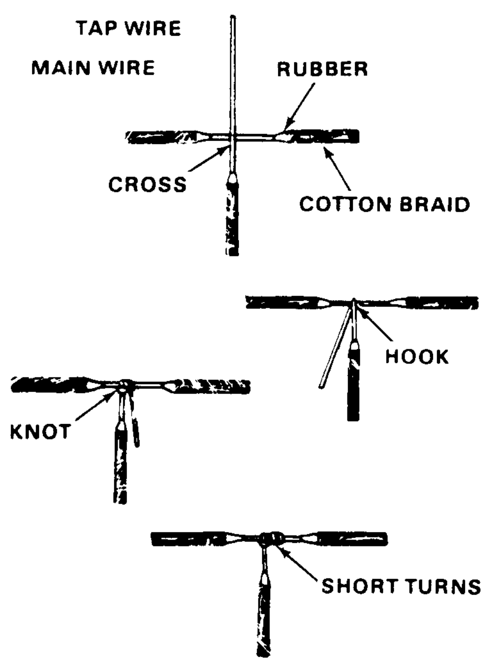


PIGTAIL SPLICE

T (Tee). Used to join a tap (secondary) wire to a main line.

Procedure:

1. Remove sufficient insulation and clean the conductors.
2. Lay the tap wire across the main wire so that about 2 inches overlap at a 90–degree angle.
3. Clamp the wires at the crossing point with a pair of long-nosed pliers.
4. Twist the tap wire around the main wire at least three or four times, using small, tight wraps. The finished connection should look like the letter "T."
5. Crimp down or cut off excess wire on the ends.



TEE SPLICE

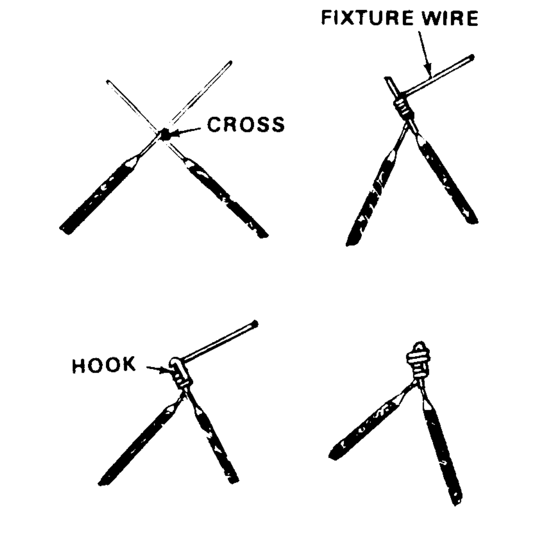
Fixture. Used to join a small wire to a large one, or to join a thin wire to a thick one.

Procedure:

1. Remove sufficient insulation and clean the conductors.

2. Overlap the two wires. Wrap the small or thin wire around the solid or heavy one at least three or four times.

3. Bend the end of the large wire over the joint. Wind the rest of the small wire around the large one.



FIXTURE SPLICE

Multiconductor Cable Repairs

Partial repairs to multiconductor cables may be required as a temporary expedient, but they are not authorized. When temporary splices are required, any of those described previously may be used. When more than one conductor is cut simultaneously, rejoin the matching colors (such as red to red or green to green).

Making temporary repairs on a multiconductor cable can be dangerous because moisture sometimes collects between the outer and inner protective coverings. Maintenance personnel must carefully check a multiconductor cable for moisture before working on it. Repair multiconductor cables that contain moisture only if drying equipment is available. Send all moist cables to the direct support unit if proper drying equipment is not available. Complete the following steps in sequence to repair a cut multiconductor cable:

1. Remove sufficient insulation and clean the conductor.

2. Twist the ends of any cut fillers and tie them together.

3. Join the stripped ends of the cable by pushing them together until the wires mesh. At least 1/4 inch of the wires at each end must be meshed together.

4. Solder the wires together.

5. Perform a continuity test, as described on page 80.

6. Insulate the soldered connection using electrical tape. To do this, twist the cable as if wringing out a towel to form a smaller diameter splice. Then apply several layers of electrical tape to the soldered area.

Distribution Cable Inspection

Operators must inspect an electrical distribution cable when it is hooked up initially, before repairs are made, and before the cable is hooked up after repairs. Complete the following steps in sequence to inspect a distribution cable:

WARNING

Disconnect the cable from the power source before starting the inspection.

1. Clean the cable assembly to remove grease, dirt, corrosion-preventive compound, and foreign material.
2. Inspect the cables for cracks, breaks, or burns.
3. Inspect the receptacles and plugs for loose connections or burns.
4. Inspect the conductors and terminals for corrosion, loose connections, or burns.
5. Inspect exposed wires for damage, corrosion, or loose connections.
6. Inspect all painted surfaces for bare spots or scales.
7. Perform a continuity test on each conductor.

Continuity Test

A continuity test is performed on an electric distribution cable to determine if the path for current flow is complete. The test determines if the conductor is broken. It does not determine the current carrying capability of the conductor. Report to support maintenance if additional tests are required.

Use a multimeter and complete the following steps in sequence to perform the continuity test:

1. Prepare the multimeter for testing resistance, as outlined in the multimeter operator's manual.
2. Touch a test lead probe to one end of the conductor; then touch the other test lead probe to the other end of the conductor. Any reading on the multimeter indicates the path for current flow is complete. The reading indicates the resistance of the conductor. For example, a l-mile long, No 6 American wire gage annealed solid copper wire has a resistance reading on the multimeter of 2.13 ohms at 77°F (25°C).
3. Repeat step 2 for all conductors.

BATTERY MAINTENANCE

Batteries must be maintained properly. The checks and services required for batteries, some maintenance problems, and possible solutions follow:

WARNING

> Do not smoke or use an open flame near a battery. Batteries generate hydrogen gas, which is highly explosive. Remove all jewelry and use metal tools with care. Metal can cause sparks when it touches battery terminals or exposed wire.

Checks and Services

To ensure the charging system works properly, operators must read the charge indicator each time the generator is started. The indicator shows a low rate of charge immediately, after the engine starts if the battery is fully charged. A partly discharged battery shows a high rate of charge for about 15 minutes.

Operators can correct many battery malfunctions. Some common malfunctions and possible solutions to them follow. Report to the next higher level of maintenance if the suggested solution does not correct the problem.

Problem	Possible Solution
Corroded connections	Clean corrosion from all connectors, terminal lugs, holddowns, and the battery top.
Deformed connectors	Replace or repair deformed connectors and battery ends that touch or almost touch.
Loose connectors	Ensure connectors are all the way down on the battery posts and are fastened securely.
Loose cable terminal lug	Tighten the cable on the connector so that the cable will not move when a reasonable force is exerted.
Loose battery holddowns	Tighten battery holddowns so they will hold the battery in place but not deform the battery, battery case, or battery holddowns.
Loose ground connections	Tighten the ground end of the cable. It must be tight and have a good electrical connection to the engine or the generator frame.

The generator battery must be serviced regularly. The parts to be serviced and maintenance required follow:

Caps. Remove the battery caps and inspect the vent holes. Clean dust from dirty or clogged holes.

Holddowns. Inspect the battery holddowns. Ensure the battery is held tightly in the carrier.

Electrolyte levels. Inspect the electrolyte level and add distilled water as needed. Follow instructions on the filler cap or cell cover. The electrolyte level always must be above the top of the battery plates. Add only distilled water to the battery. If distilled water is not available, use rain or drinking water. Store water for batteries only in glass or plastic containers, not metal containers. Never add contaminants or additives to the battery solution.

WARNING

Handle electrolyte with extreme care. Electrolyte contains sulfuric acid, which severely burns skin, clothing, and paint upon contact. Immediately flush water over any area that comes in contact with electrolyte to wash away all traces of acid.

Serviceability. Check the specific gravity and voltage readings. A voltmeter indicates the battery voltage. A fully charged battery electrolyte has a specific gravity of 1.225 in tropical climates and 1.280 in temperate climates. Charge the battery if the specific gravity is less than 1.180 in tropical climates or 1.225 in temperate climates. Replace the battery with a fully charged one if it cannot be charged in the field.

Terminal connections. Remove corrosion from all battery terminals and clamps. Coat the clean terminals and clamps with a thin layer of corrosion inhibitor or grease. Ensure the clamps have a good electrical connection to the terminal and are fastened securely to the battery.

Cables. Clean corrosion from the terminal lugs, and tighten loose lugs. Clean the cable insulation. Send cables with corrosion under the insulation to organizational maintenance for repair or replacement. Protect cables that pass through holes in metal with grommets. Fasten long sections of cable to a stable object that is away from moving or vibrating parts.

Removal Procedures

Complete the following steps to remove a battery. Be careful when removing the battery from the generator.

1. Turn off all electrical loads.
2. Disconnect the ground or negative cable to reduce sparking.
3. Loosen the clamping nut.
4. Remove the clamps. Spread the clamp ends carefully to avoid damaging the battery posts. Use a small puller or special tool to remove any corroded clamps. Do not pound or beat on the battery terminal.

Chapter 6

Protective Equipment, Safety, and First Aid

Installing and operating electric generating equipment is hazardous work. Equipment operators and maintenance personnel must understand how protective equipment on the generator set functions. They must use safe work methods and know how to rescue accident victims.

PROTECTIVE EQUIPMENT FOR ELECTRIC CIRCUITS

Generators in military power plants and feeders (auxiliary circuits) are protected from electrical overloads and faults with circuit breakers or fuses. Circuit breakers are preferred in most power plants because they disconnect all phase conductors at once. Fuses protect each phase independently. Thus, a fuse may blow to protect one phase, but the other phases remain energized and cause a phase imbalance.

Circuit Breakers

Circuit breakers are operated by tripping relays, tripping reactors, or thermal elements. Most circuit breakers have thermally operated tripping devices or AC reactor tripping devices plus a relay.

Operators can adjust circuit breakers to trip quickly or slowly. Adjust the breakers to trip quickly to protect against heavy overloads and faults near the power plant and on the station bus (terminal point for all circuits). Adjust for a delayed tripping to protect against light overloads and distant faults. Circuit breakers on feeder lines are adjusted to trip quickly for overloads at or beyond the feeder lines. This allows the circuit breaker for the main line to remain closed when the one for the feeder line opens.

Generator sets in military power plants usually have high internal impedance (resistance to flow of an alternating current) to limit the amount of current that can be obtained from the sets under short-circuited conditions. The maximum amount of current available is approximately

2 1/2 times the full–load amperage rating of the generator. Operators can set circuit breakers for current up to the output rating of the generator. Never set circuit breakers for current higher than the output rating of the generator.

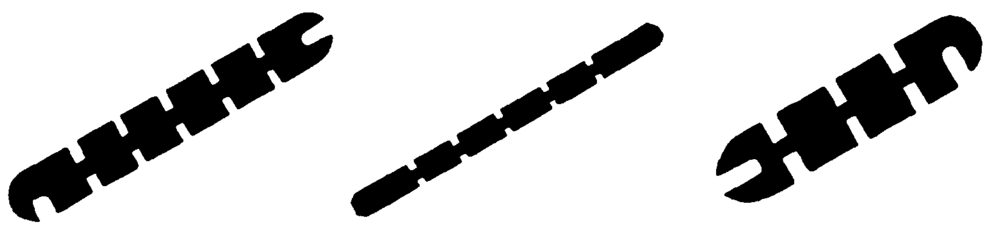
Three–phase, three-wire generator sets require two tripping elements. One element is put into action by two of the three phases. Overcurrent taken from one phase affects one or both of the other phases.

Three-phase, four–wire generator sets require three tripping elements for complete protection. An overload on one phase causes all three phases to disconnect at once.

Fuses

A fuse is an electrical safety valve. It guards electrical and electronic equipment against destructive current flow. A fuse opens the circuit when too much current flows or when there is a sudden surge of high current caused by a short circuit or an overload. The right fuse, properly installed, provides safe, dependable, and trouble–free protection. It is important to use the right type of fuse. Descriptions of the types of fuses available and their uses follow:

Link. The first type developed, link fuses are also the simplest. They consist of short, flat metal sections connected by necks. Link fuses either are soldered into the circuit with special low–melting solder or they are fastened under two binding screws in uncovered fuse holders. The links in these fuses often are used to replace links in cartridge fuses.

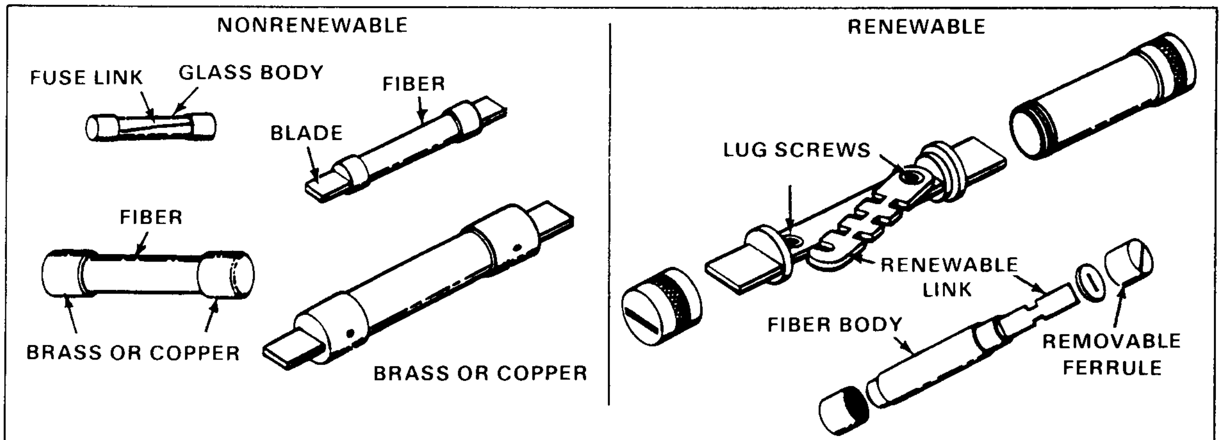


LINK FUSE

Cartridge. Cartridge fuses are the most common type. There are two kinds of cartridge fuses--ferrule and knife-blade (figure at the top of page 86. Both kinds consist of a fuse link within a hollow tube made of glass, ceramic, fiber, or other insulating material. The ends of the link connect to metal contacts (caps) at each end of the tube (cartridge). Cartridge fuses are designed for either one-time or multitime operation. One-time operation fuses cannot be repaired and are discarded when blown. Multitime operation fuses are repaired by replacing the link each time the fuse is blown.

- Ferrule cartridge fuses have low-current capacities that range from about 0.002 ampere to 60 amperes. They are used in low-powered circuits in test equipment, radios, radar sets, and vehicles.

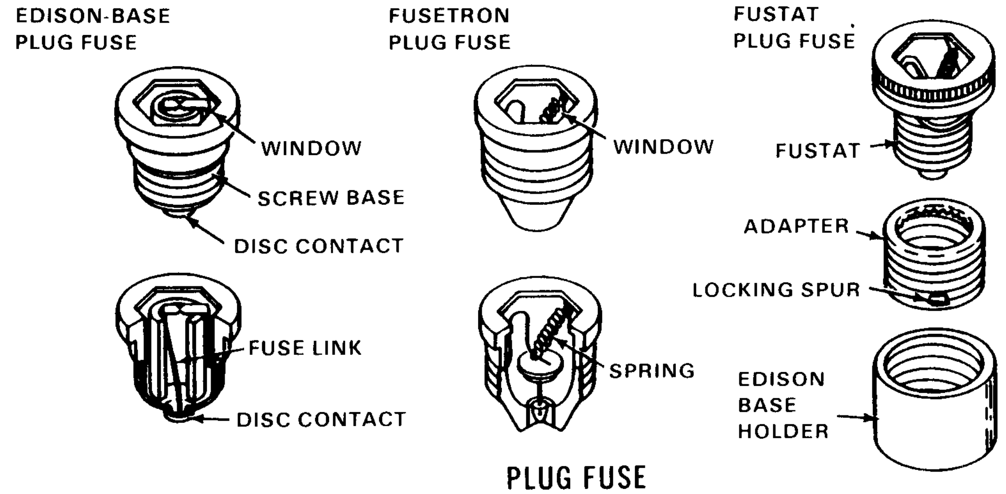
- Knife-blade cartridge fuses have high–current capacities that range from 60 amperes to more than 600 amperes. They are used in high-powered circuits such as the main circuits in homes, factories, and power plants.



CARTRIDGE FUSE

Plug. Plug fuses are often called house fuses because they are used in the 110-volt AC circuits found in most homes. A plug fuse consists of a fuse link mounted within a porcelain screw-type base. The link is connected between the metal screw threads and the metal disc contact at the bottom of the plug (figure on page 87). The link is visible through a window at the top of the fuse. Operators can look through the window to see if the fuse is blown. Some of the windows tarnish or cloud over when the fuse is blown. This feature enables operators to quickly find which one of a large bank of fuses is blown.

The current capacities of plug fuses range from 0.3 ampere to 30 amperes. They are designed to operate in low-powered circuits up to 125 volts. The fusetron and Edison-base plug fuses fit in the same standard base inside the fuse box. The fustat type requires a special adapter that fits inside an Edison base holder. While the fusetron and fustat types are designed to withstand momentary surges of excessive current, such as electric motor circuits, the Edison-base type cannot. Discard an Edison-base fuse when it is unserviceable.



PLUG FUSE

Fuse Replacement

Replace a blown fuse with an exact duplicate whenever possible. If an exact duplicate is not available, operators may need to substitute another type. Substitutions can be made in noncritical circuits only if the--

- Replacement fuse is the correct size.
- Current rating of the replacement fuse does not exceed the current rating of the original.
- Voltage rating of the replacement fuse does not exceed the voltage rating of the original.

WARNING

Turn off the power before replacing a fuse to prevent shock and injury.

SAFETY

Working with electrical circuits and equipment is dangerous. Accidents to equipment operators and maintenance workers often result in loss of work time, partial or permanent disabilities, or death. Most such accidents can be prevented if operators have safe work habits and use safety equipment properly.

Repairing and Installing Electrical Equipment

The following safety tips can help prevent accidents when repairing and installing electrical equipment:

- Insulate all exposed lines with rubber shielding or other nonconductive material when installing generators, motors, control equipment, and conductors.
- Install proper guards on all rotating or moving parts so clothing and limbs cannot catch in them.
- Leave enough space around equipment for inspections and repairs.
- Install main feeder lines and branch wiring that carries 400 volts or more in conduits or shielded cables. Cables coated with neoprene or other modern covering may be used.
- Attach a numbered, nonferrous metal Identification tag to each cable.
- Attach a tag marked with the line voltage to the line.
- Wear rubber gloves covered with a pair of leather gloves when working on electrical circuits.

Repairing and Installing Electrical Circuits

Care is required when working with or near any electrical circuit. The following tips can help prevent accidents to operators and maintenance personnel:

- Consider all voltage dangerous, even if the amount of voltage is not high enough to produce a serious shock. High voltage can transfer from circuits or operating equipment to an individual and cause a shock without actual physical contact.
- Shut off the current before examining or repairing any light or power circuits, regardless of the voltage.
- Treat dead circuits the same as live circuits: Shut off the current before examining or repairing any circuit. Remove all main circuit breaker fuses so the power cannot be turned on accidently. Attach a note to the fuse box indicating work is in progress.
- Turn off the power to the conductors before working on a live circuit remote from the control switch.

- Inspect the entire circuit before applying power to it for the first time. Ensure no personnel are in contact with operating equipment when power is applied.

- Install a grounding circuit on large capacitors to eliminate voltage charges.

- Shut off the main circuit breaker before servicing any part of a generator set and before connecting a load. Ensure the set is not connected to an energized line.

- Stop both generator sets before making a parallel connection between them. Ensure neither of them is connected to an energized line.

- Ensure the load does not exceed the rated capacity of the operating generator before placing the main circuit breaker in the on position.

- Stop the generator set and disconnect it from all external lines before starting any maintenance procedures on the controls, instruments, or wiring.

Grounding

All electrical equipment such as generator sets, motors, conduits, switch boxes, transformers, and portable power tools must be adequately grounded when in use. Never operate a generator set until the grounding terminal is connected to a suitable ground. Electrical faults in the generator set, load lines, or load equipment may cause death by electrocution if the operator makes contact with an ungrounded system or circuit.

Grounding prevents shocks caused by improper insulation, insulation failure, or current from other line circuits that is in contact with the equipment. Remember that current will flow to the ground if voltage or a circuit is present. Therefore, operators and maintenance personnel must take precautions and be properly insulated at all times when working on electric wires, cables, or equipment.

Extra precautions are needed when working in damp or wet areas because water conducts electricity. To prevent shock injury from a live circuit under these conditions, use additional insulation such as rubber mats.

Safety Procedures

The following procedures will help operators and maintenance personnel avoid accidents while using or repairing electrical equipment:

- Use the right safety device for the work being performed. Do not rely entirely on a safety device to prevent an accident because it may fail.

- Rope off an area around the equipment being serviced to protect people who are not involved in the operation.
- Write a note with adequate instructions about the equipment and possible job hazards before leaving the work site for any reason.
- Use rubber mats or other insulating material to protect against shocks when working on the circuits for high-tension switches.
- Stand or sit on a wooden platform or stool when working in damp or wet areas. Place a rubber mat or other nonconductive material on top of the wood.
- Open and close switches quickly. Arcs may occur at the contacts if the switch is opened or closed slowly. Do not touch the contacts to determine if the power is on.
- Keep metal objects such as tools and oil cans away from field magnets. Otherwise, they may be magnetized and drawn into moving equipment parts or electric circuits.
- Ensure the exhaust gases from a generator operating within an enclosed area are piped outside.
- Provide a metal-to-metal contact between the container and tank when refueling equipment. Otherwise, sparks may be generated as the fuel flows across the metal.
- Remove all jewelry and metal items before working on electrical equipment. Ensure clothing has no exposed metal zippers, buttons, or other metal fasteners. Electrical contact with a metal object may cause a severe burn.
- Keep the work area around electrical equipment and cables dry at all times. If the work area is damp, use insulated materials to avoid serious shocks.
- Use caution when removing the cap from a radiator that contains hot engine coolant. Rotate the cap slowly to reduce pressure in the cooling system. Quick removal may allow hot engine coolant to escape and injure personnel.
- Never smoke or use an open flame when servicing batteries because batteries generate hydrogen, a highly explosive gas.
- Rinse clean water over any skin, clothing, or work area that comes in contact with the electrolyte in a battery. Electrolyte contains sulfuric acid, which causes serious burns.

- Use only distilled water in nickel-cadmium batteries. To add the distilled water, use a hydrometer or dropper that has had no contact with a lead acid battery.
- Wear ear protectors when operating a generator set to avoid hearing problems.
- Keep objects away from the air intake on gas turbine engine–driven generator sets. High vacuum may cause objects to be sucked into it.
- Keep personnel away from the exhaust gas flow and the plane of rotation when operating a gas turbine engine-driven generator set. The extreme heat may cause burns, and centrifugal force may cause the generator to break apart at the plane of rotation.
- Ensure the lifting device used to move a generator set has a capacity equal to the weight of the set. Lift the set only as high as necessary to get the job done. Do not allow the set to swing back and forth when it is suspended.
- Use only a carbon dioxide fire extinguisher to combat electrical fires. Direct the nozzle toward the-base of the flame.

FIRST AID FOR ELECTRIC SHOCK VICTIMS

Electric shock is life-threatening and victims require immediate treatment. Operators and maintenance personnel must know how to rescue and treat a shock victim at a moment's notice.

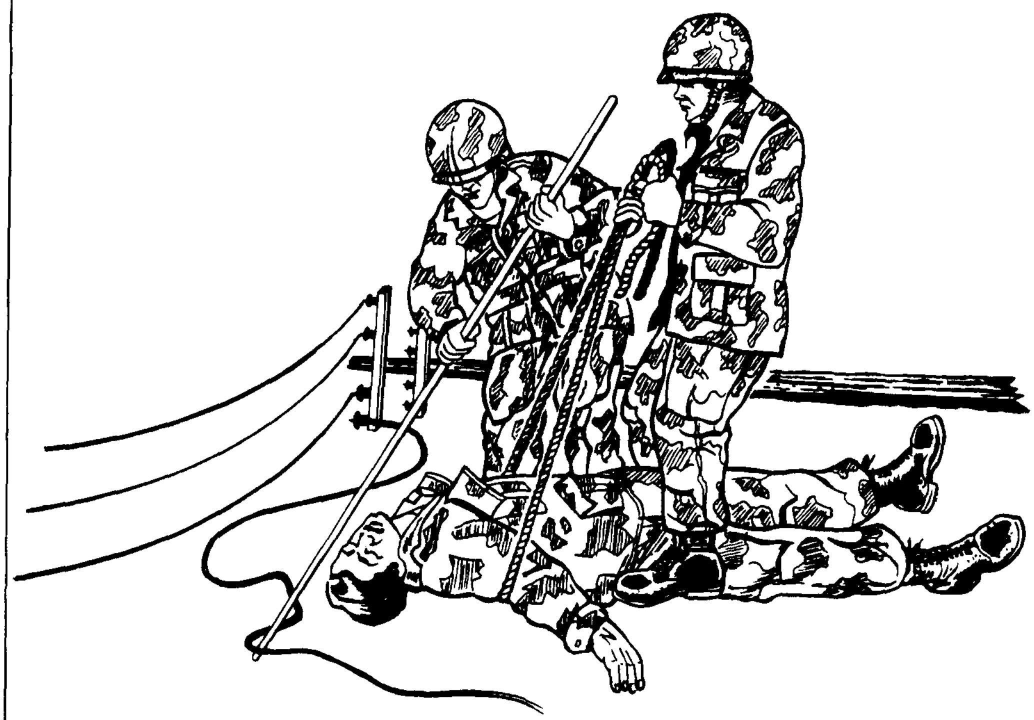
Accidents involving electric shock sometimes result from lightning strikes but most often result from contact with a live wire. The shock may cause the victim to stop breathing and the heart to stop beating. Treatment is divided into two tasks: rescue and revive.

Rescue

Complete the following steps to free a victim from a live wire:

1. Turn off the current if the switch is nearby. Do not waste time looking for the switch if its location is unknown or if it is far from the accident.

2. Use a dry wooden pole to remove the victim from the wire. If a pole is not handy, throw a loop of dry rope or cloth around the victim and drag him off the wire (figure on page 92). Any material that is dry and will not conduct electricity may be used. Do not touch the wire or the victim with bare hands or you, too, will receive a shock.



RESCUE FROM A LIVE WIRE

Revive

Complete the following steps to revive a shock victim:

1. Administer artificial respiration as soon as the victim is freed from the wire. Artificial respiration for electric shock victims must be started within a few seconds. There is little chance of recovery if the victim is not treated within 4 minutes.

2. Check the victim's pulse. If you do not feel a pulse immediately, administer cardiovascular pulmonary resuscitation (CPR) along with the artificial respiration.

3. Get medical assistance. Call or send someone for help.

4. Cover the victim if it is cold, and loosen tight clothing such as a belt or tie. Continue CPR until a qualified first-aid technician or medical authority arrives, or until you are physically exhausted.

Accident prevention and first-aid for shock victims is important to everyone concerned with electric power generation. Equipment operators and maintenance personnel must have current safety information available and be able to perform the first-aid procedures properly.

Chapter 7

Demolition Procedures

Unit commanders must ensure the enemy cannot capture or use abandoned electric generator sets or replacement parts. When capture is possible, the responsible unit commander must either demolish the equipment with explosives or make it inoperative. The following vital parts of all generator sets must be destroyed regardless of the method used:

- Axle and spring junction (wheel-mounted sets only).
- Control panel, electrical system, tubing, cables, and wiring.
- Engine block and manifold.
- Fuel filters, oil filters, fuel injection pump, governor assembly, and fuel pumps.
- Nozzle and holder assemblies.
- Radiator and hoses.
- Rocker arm covers and rocker arms.
- Starter, engine generator, engine generator regulator, and batteries.
- Water pump (water-cooled sets only).
- Winterization heater.

TRAINING

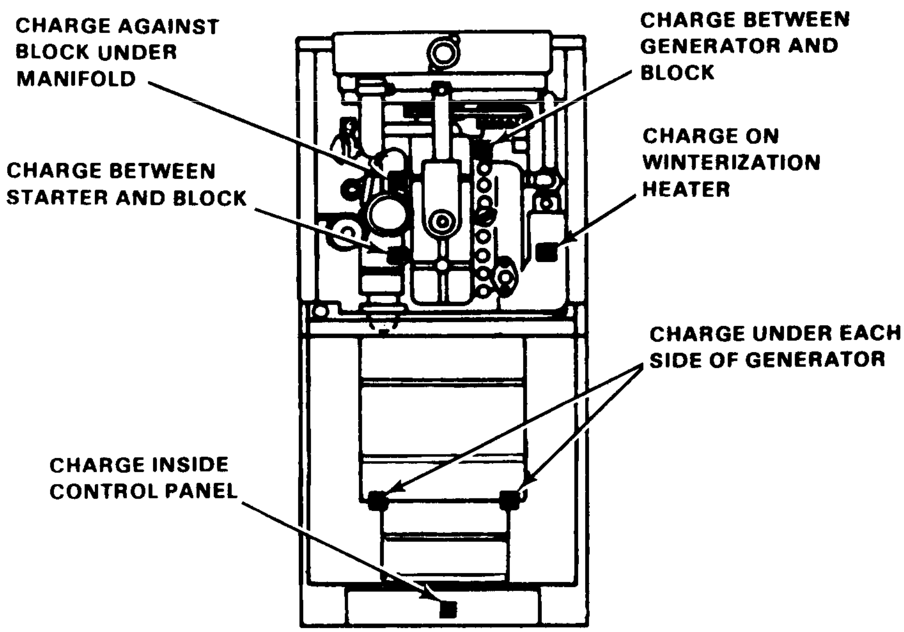
Operators must be thoroughly trained in the methods used to destroy generator sets. The training must include simulated demolition for all the methods described in this chapter. Because demolition operations usually are required in critical situations, the time available for destruction is limited. Therefore, operators must be able to complete the procedures for all demolition methods without referring to this or other manuals.

DEMOLITION WITH EXPLOSIVES

Explosives are the preferred demolition method because they completely destroy the equipment. The charges must be placed at specific points to ensure complete destruction. Demolition charges for diesel and gasoline engine-driven sets are placed at different points than charges for gas turbine engine-driven sets, as described below.

Diesel and Gasoline Engine-Driven Generator Sets

Place a l/2-pound charge at as many of the points shown on the following illustration as time allows. Set off the charges simultaneously with detonating cord and a suitable detonator.



PLACEMENT OF EXPLOSIVES IN DIESEL AND GASOLINE ENGINE-DRIVEN GENERATOR SETS

If time and supplies allow, place an additional l/2-pound charge at each of the following points in the generator set:

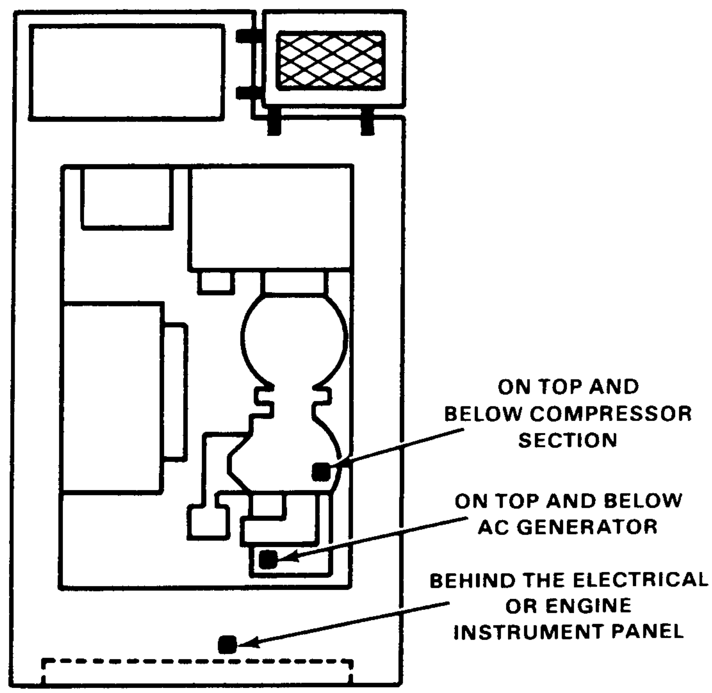
- Carburetor.
- Governor.
- Fuel pump.
- Flywheel.
- Cylinder head.

- Crankcase.
- Intake manifold.
- Exhaust manifold.
- Spring and chassis frame at mounting joint (wheel-mounted sets only).

Gas Turbine Engine-Driven Generator Sets

Gas turbine engine-driven generator sets produce from 15 kw to 500 kw of electricity. Because these generators are large, explosives are the recommended method of destruction. The charges must be strategically placed to ensure complete destruction and not just minor damage.

Place a l/2-pound charge at the points shown below:



PLACEMENT OF EXPLOSIVES IN GAS TURBINE ENGINE-DRIVEN GENERATOR SETS

DEMOLITION WITH WEAPON FIRE

If explosives are not available, use weapon fire to destroy the generator set. Fire on the set with the heaviest practical weapons available. Aim at all of the vital parts listed on page 93. Although one well-placed direct hit may render a part inoperative, several hits may be required for complete destruction.

WARNING

Assure the safety of all personnel in the area before firing point blank at the equipment.

MAKING A GENERATOR SET INOPERATIVE

Electric generators can be made inoperative by mechanical means or by misuse if they cannot be destroyed.

Mechanical Means

Operators can destroy a generator set mechanically with almost any heavy tool. Use sledgehammers, crowbars, pickaxes, or other hand tools to destroy all of the vital parts listed on page 93.

After mechanically destroying the vital parts, destroy the entire generator set with fire if quantities of fuel and flammable materials are available. Use a heavy concentration of fuel and flammable materials to produce a hot and destructive fire. Complete the following steps in sequence:

1. Pack rags, clothing, or canvas under, around, and inside the generator set.
2. Soak all packing with gasoline, oil, or diesel fuel.
3. Ignite the packing.

Misuse

If explosives, weapons, or heavy tools are not available, operators can make a generator set inoperative through misuse. Complete the following steps in any order:

- Deflate and slash the tires.
- Run the engine and pour sand or gravel into the crankcase.
- Throw sand through the ventilation screens into the main generator.
- Bypass all safety circuits. To damage the engine, drain all lubricating oil and fluid, cut all fan belts and hoses, drain coolant from the cooling system, and then run the generator set at full throttle.

DENIAL MEASURES

The enemy must be denied the use of electric generator sets and repair parts. If circumstances do not allow the equipment to be completely destroyed using any of the methods described in this chapter, conceal or submerge the sets or parts.

Conceal

Remove as many of the vital parts listed on page 93 as possible. Scatter and conceal the parts and all repair parts in caves, bury them, or scatter them in heavy underbrush.

Submerge

Remove as many of the vital parts listed on page 93 as possible. Scatter the parts and all repair parts in a body of water such as a swamp, pond, or lake. Submerge the entire generator set in the water. If available, submerge the equipment in salt water. Salt water is preferred because it damages metal parts more quickly than fresh water.

If the area is recaptured, try to recoup the concealed parts.

Glossary

AC	alternating current
ampacity	amperes plus capacity
amps	amperes
C	Celsius
CPR	cardiovascular pulmonary resuscitation
DA	Department of the Army
DA Pam	Department of the Army Pamphlet
DC	direct current
DOD	Department of Defense
F	Fahrenheit
FM	field manual
FT	foot, feet
HP	horsepower
illus	illustration
IN	inch, inches
KVA	kilovolt–amperes
kw	kilowatt
L	load
No	number
NSN	national stock number
o	degree
PMCS	preventive maintenance checks and services
RPM	revolutions per minute
TM	technical manual
	volt

References

REQUIRED PUBLICATIONS

Required publications are sources that users must read to understand or to comply with this publication.

Department of the Army Form (DA Form)

2404	Equipment Inspection and Maintenance Worksheet

Department of the Army Pamphlet (DA Pam)

738-750	The Army Maintenance Management System (TAMMS)

Technical Manuals (TM)

5-682	Facilities Engineering Electrical Facilities Safety
5-684	Facilities Engineering Electrical Exterior Facilities
5-760	Interior Wiring
5-764	Electric Motor and Generator Repair
5-6115-271-14	Operator's Organizational, Direct Support and General Support Maintenance Manual for Generator Set, Gasoline Engine Driven, Skid Mtd, Tubular Frame, 3 kw, 3 Phase, AC, 120/208 and 120/240 V, 28 V DC (Less Engine), 60 HZ, 400 HZ, and DC HZ

Technical Manuals (TM) (Continued)

5-6115-275-14	Operator's, Organizational, Intermediate (Field) (Direct Support and General Support) and Depot Maintenance Manual: Generator Set, Gasoline Engine Driven, Skid Mounted, Tubular Frame, 10 kw, AC, 120/208 V, 3 Phase, and 120/240 V, Single Phase, Less Engine; DOD Models MEP-018A, 60 HZ, and MEP-023A, 400 HZ
5-6115-323-14	Operator/Crew, Organizational, Intermediate (Field) (Direct Support and General Support) and Depot Maintenance Manual: Generator Set, Gasoline Engine Driven, Skid Mounted, Tubular Frame, 1.5 kw, Single Phase, AC, 120/240 V, 28 V DC (Less Engine) 60 HZ, and DC, 60 HZ
5-6115-329-14	Operator, Organizational, Intermediate (Field) (Direct Support and General Support) and Depot Maintenance Manual: Generator Sets, Gasoline Engine Driven, 0.5 kw (Less Engine), Utility Class, 60 HZ, Utility Class, 400 HZ, and Utility Class, 28 V DC
5-6115-332-14	Operator, Organizational, Intermediate (Field) Direct Support, General Support, and Depot Level Maintenance Manual: Generator Set, Tactical, Gasoline Engine, Air Cooled, 5 kw, AC, 120/240 V, Single Phase, 120/208 V, 3 Phase, Skid Mounted, Tubular Frame (Less Engine), Utility, 60 HZ, and Utility, 400 HZ
5-6115-457-12	Operator and Organizational Maintenance Manual: Generator Set, Diesel Engine Driven, Tactical, Skid Mtd, 100 kw, 3 Phase, 4 Wire, 120/208 and 240/416 V, Utility Class, 50/60 HZ, Precise Class, 50/60 HZ, Precise Class, 400 kw, Including Optional Kits, Winterization Kit, Fuel Burning, Winterization Kit, Electric, Dummy Load Kit, and Wheel Mounting Kit
5-6115-458-12	Operator/Crew and Organizational Maintenance Manual for Generator Set, Diesel Engine Driven, Tactical, Skid Mtd, 200 kw, 3 Phase, 4 Wire, 120/208 and 240/416 V, Utility Class, 50/60 HZ, and Precise Class, Including Optional Kits, Winterization Kit, Fuel Burning, Winterization Kit, Electric, and Dummy Load Kit

Technical Manuals (TM) (Continued)

5-6115-464-12	Operator and Organizational Maintenance Manual: Generator Set, Diesel Engine Driven, Tactical, Skid Mtd, 15 kw, 3 Phase, 4 Wire, 120/208 and 240/416 V, Utility Class, 50/60 HZ, Precise Class, 50/60 HZ, Precise Class, 400 HZ, Including Auxiliary Equipment, Winterization Kit, Fuel Burning, Winterization Kit, Electric, Load Bank Kit, Wheel Mounting Kit, and Application Kit
5-6115-465-12	Operator's and Organizational Maintenance Manual for Generator Set, Diesel Engine Driven, Tactical, Skid Mtd, 30 kw, 3 Phase, 4 Wire, 120/208 and 240/416 V, Utility Class, 50/60 HZ, Precise Class, 50/60 HZ, Precise Class, 400 HZ, Including Auxiliary Equipment, Winterization Kit, Fuel Burning, Winterization Kit, Electric, Load Bank Kit, and Wheel Mounting Kit
5-6115-545-12	Operator's and Organizational Maintenance Manual: Generator Set, Diesel Engine Driven, Tactical, Skid Mtd, 60 kw, 3 Phase, 4 Wire, 120/208 and 240/416 V, Utility Class, 50/60 HZ, Precise Class, 50/60 HZ, and Precise Class, 400 HZ
5-6115-584-12	Operator and Organizational Maintenance Manual for Generator Set, Diesel Engine Driven, Tactical, Skid Mtd, 5 kw, 1 Phase, 2 Wire; 1 Phase, 3 Wire; 3 Phase, 4 Wire; 120, 120/240 and 120/208 V, Utility Class, 60 HZ
5-6115-585-12	Operator and Organizational Maintenance Manual for Generator Set, Diesel Engine Driven, Tactical, Skid Mtd, 10 kw, 1 Phase, 2 Wire; 1 Phase, 3 Wire; and 3 Phase, 4 Wire; 120, 120/240 and 120/208 V, Utility Class, 60 HZ, and Utility Class, 400 HZ
5-6115-593-12	Operator and Organization Maintenance Manual: Generator Set, Diesel Engine Driven, Tactical, Skid Mtd, 500 kw, 3 Phase, 4 Wire; 120/208 and 240/416 V, Utility Class, 50/60 HZ, Including Optional Kits, Housing Kit Nomenclature; MEP-029SC Set Control Module; MEP-029APC Parallel Control Module; MEP-029ARC Remote Control Module; and MEP–029ACC Remote Control Cable
5-6115-603-12	Operator's and Organizational Maintenance Manual for Generator Set, Gas Turbine Engine Driven, Transportable, Skid Mtd, 60 kw, 3 Phase, 4 Wire; 120/208 and 240/416 V, DOD Model MEP-404B, Precise Class, 400 HZ
9-243	Use and Care of Hand Tools and Measuring Tools

Technical Manuals (TM) (Continued)

9-6140-200-14	Operator's, Organizational, Direct Support and General Support Maintenance Manual for Lead-Acid Storage Batteries; 4HN, 24 V MS75047-l; 2HN, 12 V, MS35000-l; 6TN, 12 V, MS35000-3
11-684	Principles and Applications of Mathematics for Communications Electronics

RELATED PUBLICATIONS

Related publications are sources of additional information. They are not required to understand this publication.

Army Regulations (AR)

310-25	Dictionary of United States Army Terms (Short Title: AD)
310-50	Authorized Abbreviations and Brevity Codes

Field Manuals (FM)

11-60	Communications-Electronic Fundamentals: Basic Principles, Direct Current
21-11	First Aid for Soldiers
21-30	Military Symbols
24-20	Tactical Wire and Cable Techniques
55-506-2	Marine Engineman's Electrical Handbook

Technical Bulletin (TB)

Sig 222	Solder and Soldering

OTHER PUBLICATIONS

Kurtz, Edwin B., and Shoemaker, Thomas M. The Lineman's and Cableman's Handbook. New York: McGraw-Hill Book Company, 1986.

Ross, Joseph A., cd., and Summers, Wilford I., tech. consultant. The National Electrical Code Handbook. Quincy, MA: National Fire Protection Association, 1980.

Summers, Wilford I., Croft, Terrell, Carr, Clifford C., and Watt, John H., eds. American Electricians' Handbook. New York: McGraw-Hill Book Company, 1981.

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